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A PLAN FOR THE APPLICATION OF ARTIFICIAL INTELLIGENCE TO DoD LOGISTICS

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This report recommends that the Office of the Secretary of Defense (OSD) move quickly to establish a program to encourage and support the application of AI to DoD logistics. The report documents the success of the private sector in applying artificial intelligence (AI), particularly expert systems, to improve logistics processes. This success is used as a model for the Department of Defense (DoD). The most appropriate AI technologies are identified. The best short-term and long-term applications areas are discussed. Finally, the report recommends specific organizational and policy actions to be taken by OSD to implement the needed program.

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LMI

Executive Summary

A PLAN FOR THE APPLICATION OF ARTIFICIAL INTELLIGENCE TO DoD LOGISTICS

As U.S. weapon systems and the logistics infrastructure become more complex, they require operations and maintenance personnel with greater skills and better training. Unfortunately, the pool of such qualified personnel is dwindling at the same time as the demand increases.

The shortage of skilled maintenance and operations technicians is not limited to the Department of Defense. United States private industry is faced with the same problem. Many U.S. companies are turning to new technologies to increase the quality of their products and the productivity of their work forces. Those same technologies are available to the Military Departments and Defense agencies.

One of the most significant of these technologies is artificial intelligence (AI). Under development for the past 30 years, AI is a family of technologies that use stored expertise and knowledge. With these technologies, knowledge, a vital corporate resource, can be captured and tested, improved and replicated, used and reused.

Six AI technologies have significant potential for application to production and logistics processes: expert/knowledge-based systems, natural language, speech recognition, three-dimensional vision, intelligent robotics, and neural networks. The most significant of these technologies thus far is expert systems. Many private-sector and DoD applications have shown that expert systems can enhance the quality and productivity of logistics systems and processes.

The largest corporate users of AI have recognized that productivity-enhancing applications of AI exist throughout their corporations at virtually every level and in every function. However, they have also recognized that AI will not be applied correctly without some formal, centralized management and support. Thus, these corporations created program offices to encourage, support, and help manage the

infusion of AI throughout their enterprises. Their experience has been highly positive and provides a model for DoD.

The Assistant Secretary of Defense (Production and Logistics) [ASD(P&L)] has established an initiative to facilitate the use of AI technologies in DoD production and logistics processes. We recommend three organizational actions to successfully implement that initiative:

- OSD should establish a DoD Logistics AI Policy Council [chaired by the ASD(P&L)] to provide DoD-wide guidance and policy direction on matters affecting the application of AI technologies to logistics processes.
- OSD should establish a DoD Logistics Artificial Intelligence Program Office for a period not to exceed 3 years with a dedicated six-person staff. The Program Office will assist the AI Policy Council in implementing DoD AI policy and in establishing a permanent DoD technical support staff. It will also promote AI throughout DoD logistics.
- OSD should establish a DoD-wide Logistics Artificial Intelligence Technology Transition Center (TTC) as a permanent group to provide the informational, technical, and managerial support services required by the logistics community.

These recommendations constitute a strategic plan designed to help DoD agencies put AI technologies to work in logistics. Implementing this plan will improve logistics efficiency, reduce costs, increase effectiveness, and decrease the time required for planning and mobilization.

PREFACE

The Assistant Secretary of Defense (Production and Logistics) [ASD(P&L)] has established an initiative to facilitate the implementation of artificial intelligence (AI) technologies in production and logistics processes. Experience has shown that AI technologies, when properly applied, are key enabling technologies that will allow the Armed Forces to sustain and enhance their critical levels of warfighting capability in the environment of the 1990s.

The plan presented here documents the actions necessary to realize all the potential benefits these technologies offer to logistics support and management over the period 1990 – 1995. The plan provides a roadmap which targets specific objectives and charts the courses necessary for their attainment.

This plan provides the ASD(P&L) and the Deputy Assistant Secretary of Defense (Logistics) with recommendations for the best use of AI in improving logistics efficiency, reducing costs, increasing effectiveness, and decreasing the time required for planning and mobilization. It outlines the organizational structure and policy needed to support the use of AI technologies in DoD logistics.

This plan is described in four chapters and five appendices. Chapter 1 assesses six key AI technologies that can be applied directly to military logistics processes. Chapter 2 reviews and analyzes AI implementation experience. In that chapter, we present a review of major AI logistics initiatives that have been undertaken by the Services; we also review the experiences of six major American corporations that are in the process of developing AI capabilities for their ongoing operations. Chapter 3 describes the need for a DoD logistics AI program, outlines the scope and objectives of the program, and summarizes the functions that such a program should perform. Chapter 4 then discusses the implementation of the DoD AI logistics program. The five appendices contain detailed information and supporting documentation.

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CHAPTER 1

ARTIFICIAL INTELLIGENCE AND LOGISTICS

MILITARY LOGISTICS IN THE 1990s

In the 1990s, several factors will combine to significantly change the practice of logistics management. Those factors include the ever-increasing sophistication of our weapon systems and the shrinking pool of available, qualified manpower. Further complicating the problem, a growing percentage of entry level workers will not have the educational background to qualify for skilled positions. Still others will be eliminated by drug and substance abuse [1]. The ability of the U.S. Military Services to maintain existing levels of warfighting capability in this increasingly complex environment will be challenged.

Furthermore, the very nature of logistics decision making is evolving and will continue to evolve in the 1990s. Computer hardware and software advances are giving workers in a variety of jobs nearly routine access to computer technology. As computers and computer programs have become more user friendly, the requirement to be technically skilled in data processing in order to gain access to, and make use of, decision support tools and to gain access to the organization's databases has nearly been eliminated. The increasing use of both computer-aided acquisition and logistic support (CALS) and electronic data interchange (EDI) is making data even more accessible to support the logistics decision-making process. Hence, we have ready access to data (resulting at times in an inundation of logistics data) and routine access to computers that can process the data. We cannot, however, translate these data to useful information and then ultimately use that information to improve knowledge and understanding of the logistics process, and without that capability the data and computers cannot be effective.

Artificial intelligence (AI) technologies appear particularly promising as tools to provide the bridge between data and knowledge. AI technologies permit organizations to capture and use, in entirely new ways, the organization's most important resource – its corporate knowledge. Knowledge is now recognized as a

vital corporate resource, a resource to be captured and tested, improved and replicated, used and reused.

ASSESSMENT OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES

Artificial intelligence generally describes software that emulates some aspects of human reasoning. Much as its name implies, it is concerned with developing computer programs to make computers smart or "intelligent." It is not one but a series of technologies that have been in constant development for the past 30 years. Those technologies include expert systems, natural language, speech recognition, three-dimensional vision, intelligent robotics, and neural networks. AI is based on the premise that common processes underlie the activities of thought and perception and these processes can be understood and functionally replicated in computers. However, the reasoning processes with which AI concerns itself are symbolic and nonalgorithmic rather than numeric. Most of the interesting knowledge that people possess is, in fact, symbolic, inexact knowledge [2]. AI attempts to understand and represent this symbolic, inexact knowledge so that it can be processed by the computer.

Artificial intelligence, however, is not a revolutionary technology. Rather, it represents an evolutionary step forward in the representation of symbolic knowledge. Important distinctions can be drawn between conventional computer programming and AI. In conventional computer programs, the instructions are explicit and define precise solution algorithms. On the other hand, AI programs do not explicitly define solution steps. They define specific control strategies, such as working backward from a goal to a solution or working forward from data to a solution. The computer then follows these strategies to generate a solution, much as an individual uses logic to solve a problem.

An AI logistics program captures and stores logistics knowledge, such as rules, policies, and logic, in a "knowledge base" in much the same way as a conventional computer program stores numeric information in a database. However, while conventional computer programs integrate the domain knowledge and the control logic, so that it is difficult to modify the program or to separate the knowledge from the control structure, AI programs clearly separate the domain knowledge from the control logic. (Figure 1-1 illustrates that separation). Because of the separation, AI programs tend to be easier to modify, update, and enlarge. AI programs can also

work with uncertain, conflicting, or missing facts, and explain the logic of a suggested solution. Figure 1-2 is a comparison of conventional and symbolic AI programming; it lists the strengths of each technique. Conventional programming and symbolic programming can and should be used together in solving complex logistics problems; each technique should be used to address the types of tasks for which it is best suited.

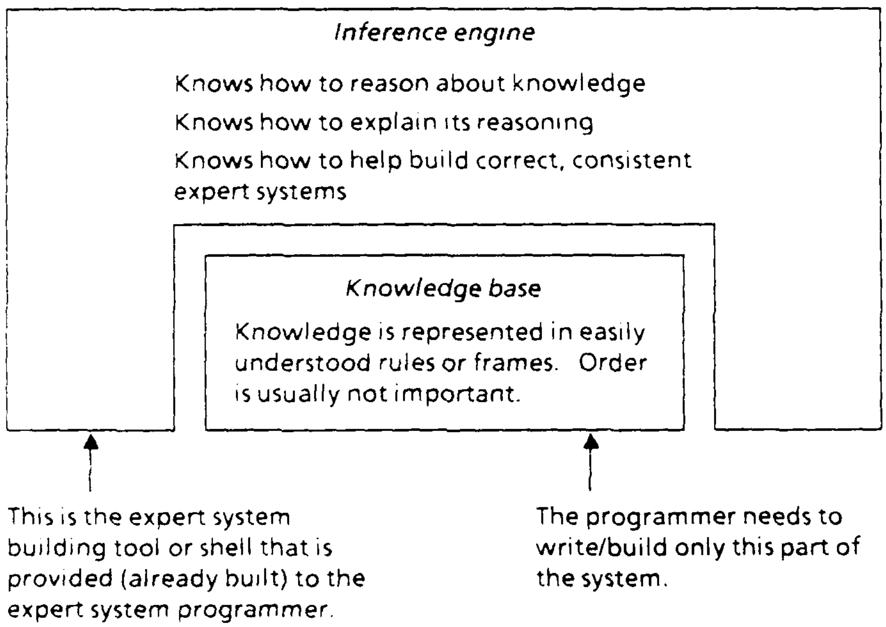


FIG. 1-1. ARTIFICIAL INTELLIGENCE SYSTEM ARCHITECTURE

Conventional programming	*Symbolic programming*
• Algorithms	• Heuristics
• Numerically addressed database	• Symbolically structured knowledge base in a global working memory
• Oriented toward numerical processing	• Oriented toward symbolic processing
• Sequential batch processing	• Highly interactive
• Mid-run explanation impossible	• Mid-run explanation easy

Source: Artificial Intelligence in Business: Expert Systems, Harmon and King, Wiley Press, 1984

FIG. 1-2. COMPARISON OF CONVENTIONAL AND KNOWLEDGE-BASED SYSTEMS

Six AI technologies have significant potential for application to production and logistics processes: expert/knowledge-based systems, natural language, speech recognition, three-dimensional vision, intelligent robotics, and neural networks. Each of these technologies is discussed in this chapter. In those discussions, we present a brief description of the technology, an assessment of the technology's current status and future potential, and actual or proposed applications of the specific technology to DoD production and logistics processes.

Expert Systems

Expert systems are software programs designed to mimic a human expert. The programs usually serve as intelligent advisors in specific areas of expertise. Many management decisions in logistics functional areas are made under complex circumstances by acquiring information about particular problems and then applying "rules of thumb," facts, heuristics, and other knowledge obtained through experience. A "knowledge engineer" may use a process known as "cognitive modeling," to encode the knowledge of the domain and the way the expert acquires, represents, and uses that knowledge. Expert systems capture the knowledge in the form of a computerized knowledge base. The expert system then uses the stored knowledge along with problem-specific information to suggest expert solutions. Expert systems expand the types of decision making that can be enhanced through automation.

To aid a manager in resolving a problem in logistics, an expert system may request some initial information about the problem from the user. It then searches the knowledge base for an entry (a rule, pattern, or model) or entries that "fit" the problem situation suggested by the initial data. This search may lead to an immediate solution. More likely, it will result in a request for additional information. That process continues until the expert system reaches a conclusion or a recommended management action. At any time during the process, a manager may ask the expert system to explain a line of questioning, the reasoning process that led to a particular conclusion, or the relevance of a recommended action.

Most expert systems can offer advice, solve problems, or make predictions with an accuracy almost as great as their human counterparts and in rare cases even better. Expert systems usually are interactive; however, they can also be used to control processes in a closed loop real-time environment, with no human intervention.

Expert system technology has some technical restrictions. Currently, expert systems can address only very narrow areas of expertise and have limited capability to encode common sense. Current research efforts are aimed at expanding their limited explanation and learning capabilities. The next 5 years should witness the development of enhanced schemas for representing knowledge, the ability to provide much better explanations, much larger and more sophisticated knowledge bases, and knowledge base sharing among numerous systems. The ability to incorporate true common sense and learning features will remain a difficult problem. Further, useful programming techniques such as object-oriented programming, model based reasoning, and generic task tools will be advanced and applied in new areas.

The ability of expert systems to encode institutional knowledge has wide-ranging advantages. Where expertise is in short supply, expert systems help increase productivity by enabling the sharing of critical skills at different sites and throughout all levels of the organization. Workers at all levels are able to deal with increasing levels of complexity because they have access to higher levels of expertise. The development of expert systems also enables an organization to assimilate the knowledge and experience of several human experts, often from different fields. Some systems are developed in the hope of creating expertise in critical areas in which not enough knowledge exists. The use of expert systems promotes disciplined application of procedures and policies, and can shorten the training time for new personnel. Expert systems are also used to provide expertise in boring or hazardous jobs that do not retain nor attract experts. Of even greater import, expert systems can provide more consistent, reliable, timely, high-quality decisions.

Expert system technology has been proven. Worldwide, more than 2,000 expert/knowledge-based systems are in regular use in the public and the private sectors [3]. In the private sector, wholesalers, retailers, and manufacturers use expert systems daily in all functional areas. Digital Equipment Corporation (DEC) uses 50 expert systems on a daily basis [4]. Some of the benefits of these systems are difficult to quantify, "but overall the net return to Digital is estimated to be in excess of $40 million per year" [5]. International Business Machines (IBM) has nearly 400 expert systems in use and under development. It claims a net return of $38.5 million a year on its six leading expert system applications [6]. Du Pont has more than 600 expert systems in use and claims annual returns of 15 to 1 on those systems [7].

Commercial Logistics Applications

Many of these expert system applications address real-world logistics operations. The Eastman Kodak Company uses an expert system in its Atlanta and Dallas distribution centers to greatly improve the productivity of its work force in picking material and correctly placing it on pallets. This expert system is based entirely on personal computers (PCs) [8]. It examines the line items on a customer's order and decides (1) how to build pallets of product that are ready to ship to the customer and (2) how to select the best "pick path" through the warehouse. To develop the expert system, an experienced order puller's thinking process was captured and made available to everyone. As a result, pick productivity was increased, and the training period for new people was reduced from 30 to 60 days down to 1 to 2 days.

General Motors (GM) uses expert systems for scheduling its manufacturing operations and for a number of diagnostic tasks. It uses an expert system called "Charley" to analyze the vibration signatures of machines and to assist in the diagnosis of machinery problems. For 23 years, Charley Amble was GM's resident vibration analysis expert. He diagnosed real and potential maintenance problems on plant floor machinery by analyzing machine vibration signatures. Because his retirement in 1986 would have meant not only the loss of his expertise but also increased training costs and reduced levels of machine maintenance, GM decided to "clone" Charley's knowledge of machine vibration signatures. "Charley" is now in use at three GM plants in Michigan and when in full production, will be installed at 20 of GM's North American plants. At the Saginaw plant alone, Charley has saved approximately $65,000 by diagnosing problems in three different machines before complete failure occurred. GM estimates that each machining plant that uses the expert system will see cost savings of nearly $500,000 per year [9].

Burlington Northern Railroad uses an expert system that identifies scheduling conflicts among trains and track maintenance gangs. Called the Service/ Maintenance Planner, it recommends solutions to these conflicts. In scanning the February and March 1989 schedules, for example, the system identified solutions saving more than $100,000 in costs associated with train delays and wasted maintenance gang time [10].

Digital Equipment Corporation has been using expert systems for logistics since the early 1980s. One of its most successful applications is a system called "Dispatcher" which keeps track of work-in-process (WIP) inventories. Dispatcher is integrated with the company's materials handling and supplies ordering system. It ensures WIP inventory is always being processed by an available workstation. Further, it sees that orders for supplies and component parts are placed as soon as a need is identified. Dispatcher has enabled DEC to cut its WIP cycle times from 36 days to 5 days [11].

Texas Instruments uses expert systems to help customer service representatives answer more questions than would otherwise be possible [12]. The Federal Mogul Corporation uses an expert system to assist in forecasting requirements for inventory [13]. IBM uses an expert system called MOLDCOST to assist in the purchase of injection moldings. The system saves IBM $1.5 million annually [6]. Literally hundreds of additional logistics applications are in use by companies as diverse as American Airlines, Mervyns, Marshalls, Federal Express, DuPont, Westinghouse, and Ford.

DoD Logistics Applications

Expert system technology has also been applied to all functional areas of production and logistics throughout DoD. Today, more than 400 logistics expert systems are under development or in use in areas of inventory management, transportation, warehousing, acquisition, maintenance, and production. For example, the Air Force has fielded the Inventory Manager's Assistant, an expert system that validates the data used in the computation of reparable assets forecasting. During its first field test the system identified a $600,000 cost savings [14].

The Joint Chiefs of Staff (JCS) is supporting the development of the Logistics Intra-theater Support Tool. It gives advice on the adequacy of a theater's infrastructure to support the movement of specified ground forces and supplies to a given destination by a specified day [15].

The Navy is currently fielding an expert system – the Dues Management Advisor (DMA) – that assists in the management of critical items. It was developed to assist Navy inventory personnel manage past-due replenishment orders for retail items at a number of supply centers. Specifically, it identifies and sets priorities for

the most critical past-due items for management attention at any given time. The use of DMA is expected to result in faster resolution of past-due situations and more consistent application of procedures [16].

The Army is developing the Logistics Planning and Requirements Simplification (LOGPARS) system. It offers integrated logistics support (ILS) expertise to assist in the development of the ILS strategy and readiness objectives [17]. Each of the Services has several expert systems that assist with the diagnosis and fault isolation of sophisticated weapon systems, and numerous other expert systems are in use or under development.

Natural Language

Natural language is the second important AI technology. Natural language systems can convert a language such as English, French, Japanese, or German into computer language. With natural language systems, we can communicate with computers in our native language, thus eventually eliminating the requirement to learn computer languages. Furthermore, natural language systems make our logistical databases easier to access and use.

With some limitations, natural language technology is commercially available today. Natural language interfaces are available for both PCs and mainframe computers. The first commercially available natural language systems for mainframes were introduced in the early 1980s, and PC-based versions appeared in the mid-1980s. Most of the tools that are available today require either a structured form of query or a specific relational database management system interface. We have not yet developed tools that permit unstructured queries of flat files. Restrictions on the use of natural language tools will be reduced and much more powerful capabilities will continue to be introduced over the next several years.

Natural language applications are being examined for their potential use in DoD. Among the projects proposed is one that would combine the use of natural language with an expert simulation to provide action officers in the Pentagon with a query capability to do what-if analyses on budget cuts. Such a system would permit action officers to type questions like "What other programs will be affected if I cut the fuels budget by $500 million?" and receive a response. Numerous other agencies

throughout DoD have suggested the use of natural language systems to provide user-friendly query capability for their huge logistical databases.

Speech Recognition

Speech recognition and understanding is the third key AI technology. Speech recognition systems permit us to talk directly to computers and eliminate the requirement for keyboard entry. All speech systems work in essentially the same way: An analog voice signal is digitized and compared with stored patterns to recognize what was said, and stored grammatical rules are applied to determine the meaning conveyed by the words. The simplest analysis technique is template matching. It consists of comparing the digitized input signal with stored templates in the system until a match is found. Such simple pattern matching might suffice for discrete speech (i.e., isolated words with a distinct pause between words) from a single user. However, speaker-independent systems that must understand continuous speech require much more sophisticated recognition algorithms. Furthermore, as one might expect, the larger the vocabulary the computer must recognize, the more complicated the systems become.

Commercial Logistics Applications

Speech recognition systems are commercially available today. However, the types and capabilities of these systems are still somewhat limited. Current speech recognition technology is largely dependent upon the requirements of the system and its environment, e.g., whether the system is speaker-dependent or speaker-independent; whether the speech is isolated, connected, or continuous; the size of the vocabulary; the noise level of the operating environment; and the stress of the operator whose speech must be recognized.

At the Ford Motor Company, inspectors use a speech recognition system in the form of wireless microphones and headsets, which are tied into the company's central management information system. As the cars come down the assembly line, the speech system automatically prompts the inspectors to respond to all the items on the quality control checklist. This system ensures real-time data capture and also ensures the inspectors totally comply with the appropriate checklist. If an inspector fails to respond to an item on the checklist, the line stops. The speech system uses discrete speech and a limited vocabulary to improve accuracy. This is an example of

how AI technology can be used to implement the Total Quality Management Program.

DoD Logistics Applications

The Army's Tank and Automotive Command (TACOM) is using a speech recognition system combined with an expert diagnostic system for the maintenance of its general-purpose motor vehicles. Technicians fixing the vehicles wear headsets equipped with wireless microphones that permit them to receive instructions from the expert diagnostic system and to communicate with the system while under or moving about the vehicle to check for symptoms or to make repairs.

The Air Force Logistics Command (AFLC) is using a speech recognition system in one of its depot warehouses to interface with the warehouse's automated storage module (ASM). The warehouseman (wearing a wireless microphone and headset) picks up an item from a container of incoming goods and reads the part number aloud. The system updates the inventory and provides instructions to the warehouseman to tell him the row in which to place the item. The warehouseman places the item in the appropriate container in the row, and the ASM automatically stores the item. These items are not bar coded, and prior to the implementation of the speech system, the warehousemen had to manually key the data into the interface to the ASM. That process led to numerous typing errors. Speech systems can significantly increase inventory accuracy simply by eliminating typographical errors generated at the keyboard.

Three-Dimensional Vision

Three-dimensional, or stereoscopic, vision is an AI technology that permits a computer to "sense" its environment, thereby classifying objects and avoiding obstacles. As does human eyesight, stereoscopic machine vision merges two pictures into a single image and calculates the depth by measuring the displacement of the object between the two pictures or "eyes."

In developing three-dimensional vision systems, the major problem is to bring the images from the two cameras or sensors into alignment quickly enough to perform practical real-world tasks. The algorithms designed to permit three-dimensional vision tend to be computationally expensive, and for that reason, few applications of such vision are practical today. Another real problem with

three-dimensional vision systems is that our environment tends to be quite "noisy." Rarely do we find an object with clear unobstructed edge lines. We are much more likely to find a desk cluttered with books and papers, and that clutter interferes with attempts to recognize the desk from stored patterns programmed into the computer. To deal with this and other problems, we can program algorithms as cooperative computations, in which local operations are performed in parallel on all parts of the data.

Using very complex algorithms and taking advantage of parallel computing, we are today at the stage of commercial two-and-a-half-dimensional vision. Software development tools, which permit users to develop their own machine vision systems, are commercially available. Although these tools run on special-purpose AI machines, they will soon be ported to the engineering computer workstations built by Sun Microsystems and to Macintosh II computers built by Apple Computer.

The Air Force is investigating applications of three-dimensional vision systems that would permit maintenance personnel to reverse engineer parts and collect data for reprocurement or remanufacture of those parts. The Navy is also examining the potential of three-dimensional vision systems as part of their Rapid Acquisition of Manufactured Parts (RAMP) program. Stereoscopic vision is also necessary for truly intelligent robotic systems to be used as order pickers in the warehouses of the future.

Intelligent Robotics

Intelligent robots are manipulators, or complete mobile systems, that combine expert systems, natural language, speech recognition and understanding, and vision systems to create entities capable of flexible operations that humans might otherwise perform. Flexibility is the key requirement. The intelligent robot must be able to respond flexibly to new and unique situations. For such a system to operate effectively in a new environment, it must be able to devise a strategy, sense any obstacles that would prevent it from executing the strategy, and achieve the objective. Hence, the ability for the intelligent robot to accurately recognize patterns and identify objects in real- or near real-time is critical.

Truly intelligent robotic systems capable of both movement and true three-dimensional vision are limited to the research laboratory at this time. Although

significant progress is being made in these areas, existing robotic systems are much too slow for real-world implementation.

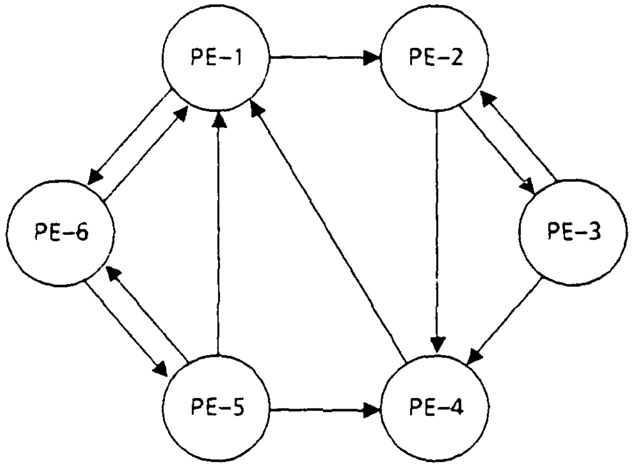
The Department of Defense, however, is investigating logistics applications of intelligent robotics. In an Air Force research project at one of its maintenance depots, an intelligent manipulator is tasked with removing rivets and fasteners from the wings of F-16 aircraft. The Navy has similar projects under way as part of its RAMP initiative.

Neural Networks

The final AI technology area discussed in this plan is neural networks, an area also known variously as neural computing, neural networking, connectionism, and adaptive systems. Neural networks are based on theoretical models of how we believe the human brain works. The basic building blocks or cells of the brain, neurons, are interconnected by synapses. Neural networks are made up of different numbers of processors, which serve as neurons. These neurons are connected to many other neighboring neurons to form a complex network (Figure 1-3). These processors communicate with one another across the connections by providing signals that activate or inhibit processing by those neurons or processors to which they are linked (Figure 1-4). Hence, a given neuron might simultaneously receive inputs from many other neurons. If the sum of those inputs exceeds a set threshold value, the neuron is said to "fire." That firing, in turn, causes the neuron to produce an output signal, which is transmitted to all the neurons with which it is connected.

Neural networks offer several advantages over conventional computing. First is the concept of adaptive behavior or learning. Neural networks are also capable of "associative recall," which is the ability to reach a conclusion or recommend an action even when an exact match to stored patterns cannot be found. The ability to "discover" novel patterns or statistically significant characteristics among data is still another desired attribute of neural networks. Finally, because of their numerous interconnections and massively simultaneous processing, neural networks will, we hope, some day be able to quickly derive solutions to problems that involve combinatorial or exponential explosion of the number of feasible solutions.

Neural network technology has seen very limited practical application to date. Today's numerous neural network models differ from one another in the number of neurons or nodes they contain, the way in which those neurons are interconnected,



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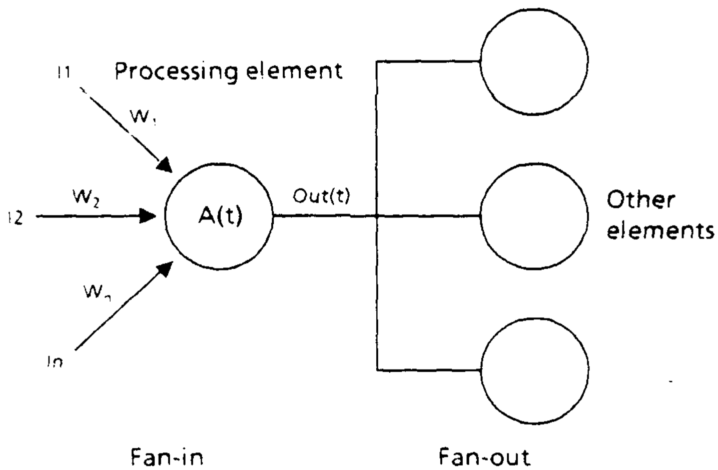
Note: PE = processing element.

FIG. 1-3. A NETWORK OF PROCESSING ELEMENTS



Source: Copyright Intellogistics, Inc. 1988
Note: I = input value; W = input weight; A(t) = threshold weight; Out(t) = output value

FIG. 1-4. A TYPICAL PROCESSING ELEMENT

and the rules used to produce each neuron's output signal. Tools to develop neural solutions are available for both microcomputers and mainframes. The next 5 years should witness a significant increase in the capability of this technology area.

Numerous DoD agencies are experimenting with neural networks. The ability of the technology to recognize patterns in huge databases is one especially promising logistical application. The Air Force is currently supporting a research initiative to determine new information about trends in engine failure by having a neural network analyze the Comprehensive Engine Management System (CEMS) database. The system is designed to determine whether any patterns in engine usage can help forecast the life span of the engine based upon the circumstances of its usage. The Air Force has also proposed to replace a human inspector with a camera tied to a neural network to perform nondestructive inspection of parts. The system would be able to more accurately and consistently examine the parts to check for stress and existing or potential structural problems.

CHAPTER 2

ARTIFICIAL INTELLIGENCE IMPLEMENTATION EXPERIENCE

CURRENT INDUSTRY ARTIFICIAL INTELLIGENCE PROGRAMS

Several major U.S. industrial companies have made "corporate commitments" to use AI technologies to achieve higher profits and productivity. As early as 1984, Senior Vice Presidents and Chief Executive Officers (CEOs) at companies such as DEC, IBM, GM, Du Pont, FMC Corporation, Lockheed, and Boeing were reviewing and approving recommendations made by corporate task forces to view AI components as strategic technologies important to their businesses and to establish program offices and/or centers to foster the use of those technologies. This chapter examines the philosophy, organizational approach, resource commitments, and lessons learned by some of those companies during the past 5 years. More detailed information about the AI involvement of these companies is provided in Appendix A.

Digital Equipment Corporation

Digital Equipment Corporation views AI as an integral part of its business success. AI has played a crucial integrating role within DEC. DEC got involved in AI originally in 1978 because it had a critical business problem that could not be solved by any other means. Today, DEC uses AI to create and manage what it refers to as the company's "knowledge network." This network comprises cross-functional knowledge and information that permits DEC to concentrate on functional boundary-spanning processes as opposed to small functional-specific tasks. As a result of the requirement for this cross-functional flow of information and knowledge, the majority of DEC's AI systems are large systems that combine AI techniques with conventional programming techniques, models, and databases. Further, these AI systems treat the flow of information, knowledge, and materials within DEC across multi-functional boundaries (see Figure 2-1). The knowledge systems and the development of these systems integrate the functional activities and should result in improved processes.

The use of AI technologies to solve key strategic business problems is part of DEC's corporate philosophy. To ensure this philosophy is communicated throughout

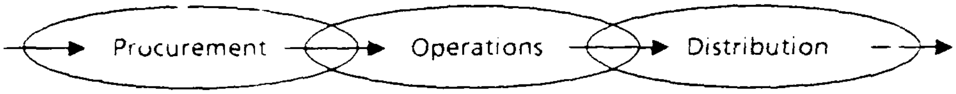
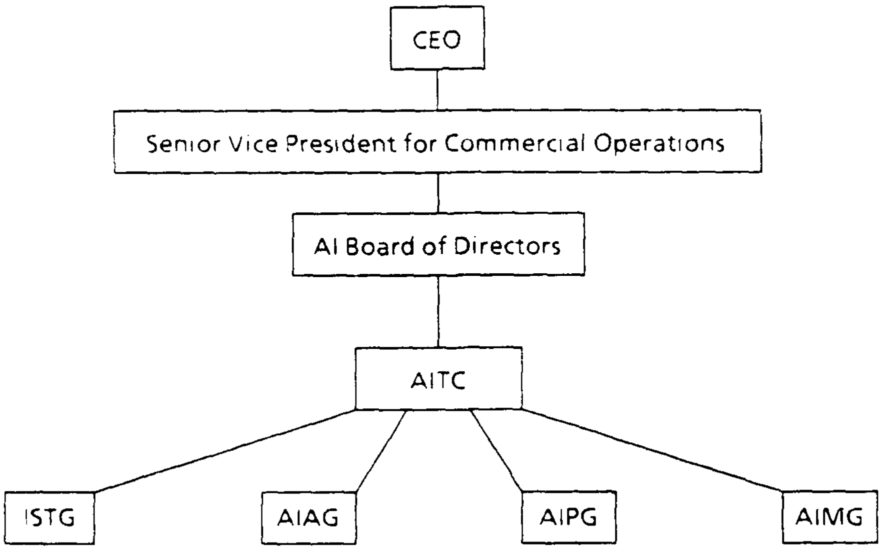


FIG. 2-1. THE MATERIALS FLOW PROCESS

the company, DEC has established an AI Board of Directors that reports directly to the Senior Vice President for Commercial Operations, and in turn, to DEC's CEO (see Figure 2-2). DEC's AI Board of Directors is chaired by the Vice President for Networks and Distributed Systems Group and its members consist of DEC Vice Presidents for Engineering, Marketing, Manufacturing, Software Services, and Field Services. The AI Board of Directors provides policy guidance and direction for DEC's AI activities.

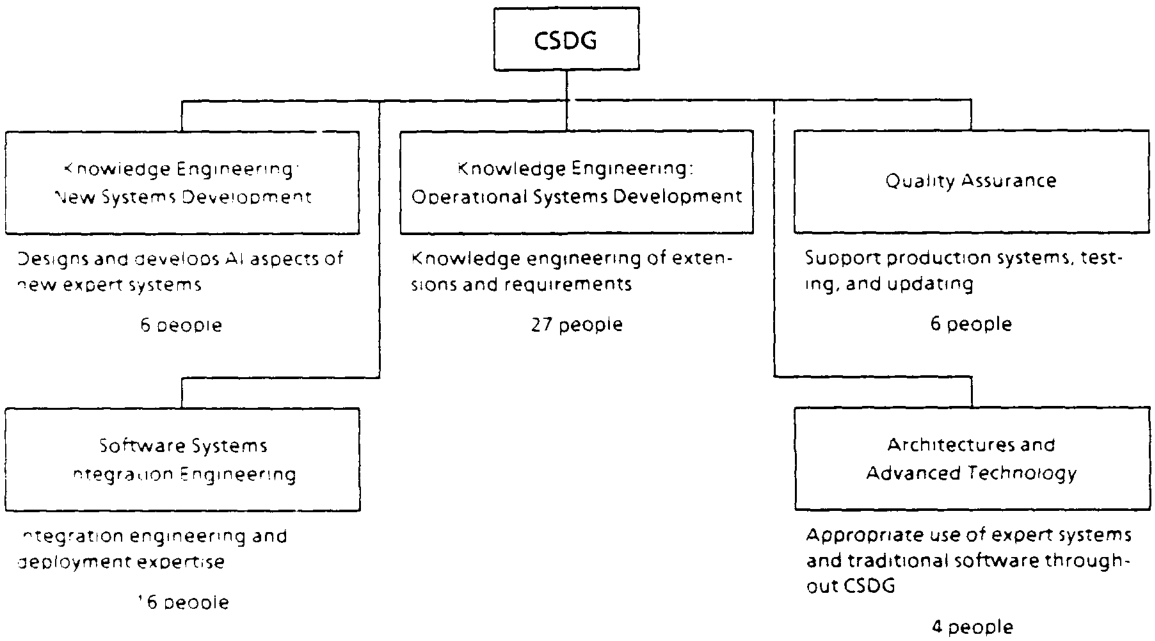


Note: AITC = Artificial Intelligence Technologies Center; ISTG = Intelligent Systems Technology Group, AIAG = AI Applications Group; AIPG = AI Product Group, AIMG = AI Marketing Group

FIG. 2-2. DIGITAL EQUIPMENT CORPORATION'S AI ORGANIZATION

Several formal groups at DEC play important roles in the implementation of AI policy guidance. Some of these activities are centralized, while others are more decentralized. The Artificial Intelligence Technologies Center (AITC) was formed in 1984 and given a permanent mandate to provide central education and training services, systems development, systems validation, and technology transition

functions. The Configuration Systems Development Group (CSDG) is a more decentralized activity. It reports to DEC's corporate manufacturing operation and is responsible for the specific activities shown in Figure 2-3 for all of DEC's configuration management systems, company-wide. Individual units are specifically charged with ensuring the integration of AI with conventional systems and also ensuring the appropriate use of the technology.



Note: Excludes business management and administrative support personnel.

FIG. 2-3. DIGITAL's CONFIGURATION SYSTEMS DEVELOPMENT GROUP

DEC stresses that total corporate commitment to AI is essential and that individuals at all levels throughout the company must be educated and involved if the program is to be successful. Table 2-1 lists the key roles and functions that DEC believes various individuals should play in ensuring a successful program. The table shows the importance of providing corporate direction and establishing policies that foster a supportive, enabling environment and permit resources to be committed. The table also highlights the important role played by experts and systems users. The domain experts are involved in systems development from the beginning of the projects. They and functional users are educated in the processes of knowledge engineering and knowledge acquisition, thereby enabling them to more readily relate

the functional requirements of the systems to the systems developers. Further, the systems developers gain a much better understanding of the basics of the business.

TABLE 2-1

KEY ROLE MODELS AT DEC

Role	Function
Champion	Has strategic vision, believes in the technology. Has political savvy and ability to provide supportive/enabling environment.
Sponsor	Ownership of business problem, commitment to solve problem, organizational stature and support, appropriate resources.
Program manager	Manages the interface between players.
Technical team: knowledge engineer	Develops and tests AI part of the system.
Software systems integration engineer	Designs and develops traditional part of system, performs release management, and supports installed systems
Experts	Provides domain knowledge.
Users	Provides knowledge of how system will fit into the current/future business process and relevant job satisfaction issues.

DEC, however, did not always have the "integration" perspective of AI that exists within the company today. Its AI program has evolved through the following three phases:

- Phase I – Getting Started
- Phase II – Developing Critical Mass
- Phase III – Integration.

For each of these three phases, Tables 2-2, 2-3, and 2-4, respectively, show what DEC considers specific objectives, unique business/strategic perspectives, technology, and human resources.

As DEC's AI program evolved from Phase I through Phase II and into Phase III, the AI program overall was given different emphasis within the company. Figure 2-4

TABLE 2-2

DEC's PHASE I: GETTING STARTED

Objectives	Learn about technology; assess applicability. Gain management support. Start small/think big.
Business/strategic perspectives	Start with important business problems; create a corporate vision.
Technology	Select problems big enough to be meaningful. Select problems small enough to be manageable. Stay within proven technology limits.
Human resource/ organization	Select and train knowledge engineers. Manage expectations. Assess and plan for role of management information systems.

TABLE 2-3

DEC's PHASE II: DEVELOPING CRITICAL MASS

Objectives	Make expert systems a reality by building expert system's depth (resources, applications, and commitment).
Business/strategic perspectives	Support multiple business organizations. Provide strategic/competitive advantage.
Technology	Apply technology broadly: • Domains • Techniques/tools • Paradigms • Integration with conventional systems.
Human resource/ organization	Co-residency of knowledge engineers and information systems staff. Justify investment in the technology.

depicts this transition of DEC's AI program along the differentiation/integration continuum. During Phase I when DEC was just getting started in AI, management believed that differentiating AI technologies from conventional methods and solution

TABLE 2-4

DEC's PHASE III: INTEGRATION

Objectives	Build a "knowledge network." Use the technology to integrate the business functions.
Business/strategic perspectives	Achieve • Productivity • Predictability • Control.
Technology	Appropriate application mix of expert systems and conventional technologies. Right method for the right problem.
Human resource/ organization	Business and technology planning done in concert.

techniques was important. Management gave the program considerable special attention and stressed its awareness and support of the technology. During Phase I, DEC emphasized the achievement of small, real-world business successes using AI. As DEC moved into Phase II and began to build critical mass, management relaxed emphasis on differentiation of the program. It began to actively examine ways to integrate AI methodologies with more conventional systems and techniques. In Phase II, DEC management emphasized the business organizations and the ability to provide them with strategic, competitive advantage; it stressed the business perspective since the technology perspective had been given more emphasis during Phase I. Finally, during Phase III management placed emphasis on applying AI along with other technologies to create an integrated knowledge network throughout the company. By integrating AI with existing systems and methods, the company is able to extract a greater return on investment (ROI) by better leveraging the prior investment in the existing information system infrastructure. Further, the emphasis during Phase III is on the corporate processes rather than on the separate functions that comprise the processes.

International Business Machines Corporation

In 1985, IBM made a top-level management commitment to use AI. Its Corporate Management Committee, comprised of the CEO, Chairman of the Board,

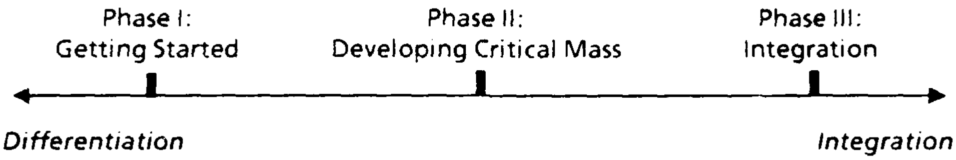
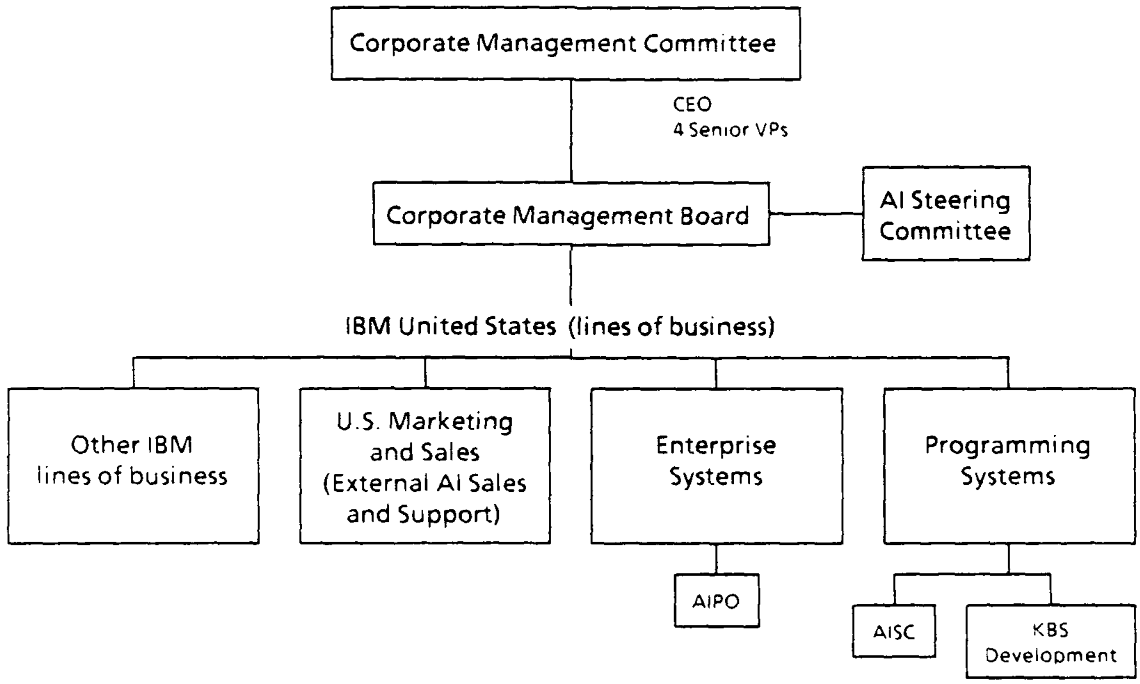


FIG. 2-4. DEC's DIFFERENTIATION/INTEGRATION SPECTRUM

and several Vice Presidents, tasked the Vice President of Systems Research Division to head the effort (see Figure 2-5). As shown, IBM, like DEC, has a very senior level group tasked with providing policy guidance and direction for the AI program within IBM. This group is IBM's AI Steering Committee.



Note: AIPO = AI Project Office; AISC = AI Support Center; KBS = knowledge-based systems

FIG. 2-5. AI STRUCTURE IN IBM

In 1985, IBM established an AI Project Office (AIPO) as a temporary organization that was to exist for approximately 3 years; it was officially disbanded on 30 June 1989. IBM established the AIPO to solidify its project plan for expert systems, to develop an internal AI use program, and to develop marketing strategies and plans for external sales of such IBM AI technology products as its expert systems

development software. Fourteen persons manned the project office and worked to help inform management of the AI program, to provide management with an understanding of AI initiatives already under way within IBM, and to integrate the varied and dispersed expertise and tools already available within IBM. The project office also provided seed money to fund strategic AI applications in IBM.

IBM also established an AI Support Center (AISC) to provide support to organic development efforts. It serves as a central organization to provide consulting services, education and training services, information services, and communications services throughout IBM. Table 2-5 presents the functions assigned to IBM's AISC. Unlike the Project Management Office (PMO), the AISC has a permanent mandate. The AISC trains approximately 1,000 IBM personnel each year and helps 61 different user groups by sponsoring conferences and by collecting and distributing technical information and lessons learned.

TABLE 2-5

FUNCTIONS OF IBM's AI SUPPORT CENTER

Role	Function
Education	Introductory/overview basic skills
Consulting	Opportunity identification Technology selection Prototyping Problem assistance
Clearing house	Application inventory
Communications	User groups Conferences Electronic note boards

Knowledge-based systems (KBS) development activity within IBM is both centralized and decentralized. Nearly 800 IBM personnel are actively involved in decentralized systems development. However, IBM also has a central group of developers located at their KBS Development Laboratory (see Figure 2-5). IBM, like DEC, has established key roles for individuals at all management levels. Those roles

are shown in Table 2-6. Senior management determines how expert systems fit into the company's overall strategy. Line managers identify projects and secure expert involvement and funding. Domain experts are responsible for transferring functional and process knowledge to the systems developers.

TABLE 2-6

MANAGEMENT ROLES AT IBM

Position	Function
Senior Executives	Strategy Organization
Line Executives	Project direction Domain experts Funding
Domain Experts	Knowledge transfer Marketing

Du Pont Company

Du Pont began its involvement in AI in 1985 with efforts to develop small in-house expert systems. Unlike DEC, which placed primary emphasis on the development of large integrated systems, Du Pont was interested in having users build and maintain their own systems to address narrow problems within specific functional areas. Du Pont established an objective of making every individual throughout the company aware of AI technology.

Dr. Edward Mahler, the Director of Du Pont's AI program, wanted to train every engineer within the company to be as familiar with KBS development tools as they were with Lotus 1-2-3 spreadsheets. Development by actual users on their PCs was the order of the day. Because no commercially available expert system development tool was deemed simple enough to be used by non-AI specialists in 1985, Du Pont developed its own user-friendly expert system development tool called "Tool Kit." Today, more than 700 copies of Tool Kit have been distributed to Du Pont's 120 plants throughout the world. In addition, Du Pont has since purchased a company-

wide license to a recent, commercially available development tool. More than 700 copies of this newer tool have also been distributed throughout Du Pont.

Dr. Mahler served as the early "champion" of AI within Du Pont, using his own office automation budget as seed money to start initiatives. He also used his "old boy network" to attract volunteer staff to help him get the activities under way. These early efforts attracted the attention of his supervisor, the Vice President for Information Systems, who, in turn, reports to the Senior Vice President for Technology. Senior management within Du Pont then decided to consolidate Dr. Mahler's activities and formally established a small AI Program Office. A small support group of 12 persons was tasked to "catalyze the application of artificial intelligence techniques, particularly expert systems, broadly and effectively through Du Pont" [3]. Dr. Mahler was named Du Pont's Program Manager for AI. Six of his 12 staff members are assigned on a permanent basis to the program office. The other six individuals are assigned on a temporary basis from other parts of Du Pont.

The functions of Du Pont's AI program office include teaching, consulting, and operating a telephone help line. The central group also acquires corporate licenses to commercial shells to lower the costs of systems development for Du Pont's various users. Training provided by the group includes a management awareness briefing, a 4-hour course on expert systems for managers, and a 2-day training course during which functional experts learn to use the shells to develop and maintain their own systems. The central group also assesses new expert systems development tools and offers advice to individuals throughout Du Pont who are considering their purchase.

Recently, Du Pont has also begun the development of much larger systems that integrate knowledge from various functional users and combine expert systems techniques with conventional programs and operations research models. These larger, more complex systems are being developed by AI specialists under contract to Du Pont as well as by organic teams of functional experts and traditional management information system staffs.

Lockheed Corporation

Lockheed's organized involvement with AI stems from 1985 when a corporate task force decided that the company needed to understand and use the technology and recommended that it establish the Artificial Intelligence Center (AIC). Lockheed companies, however, had been conducting AI research since 1981. As shown in

Figure 2-6, the AIC is a part of Lockheed's Missiles and Space Systems Group and reports to the Research and Development Division of that group. Figure 2-7 depicts the organizational structure of the AIC and clearly shows the center's three major functions of technology development, technology transfer, and training and education. The AIC has a permanent staff of approximately 50 researchers and trainers and houses visiting staff members from other Lockheed companies and divisions. The AIC also employs part-time non-Lockheed staff, including professors, graduate students, and contracted assistants [18].

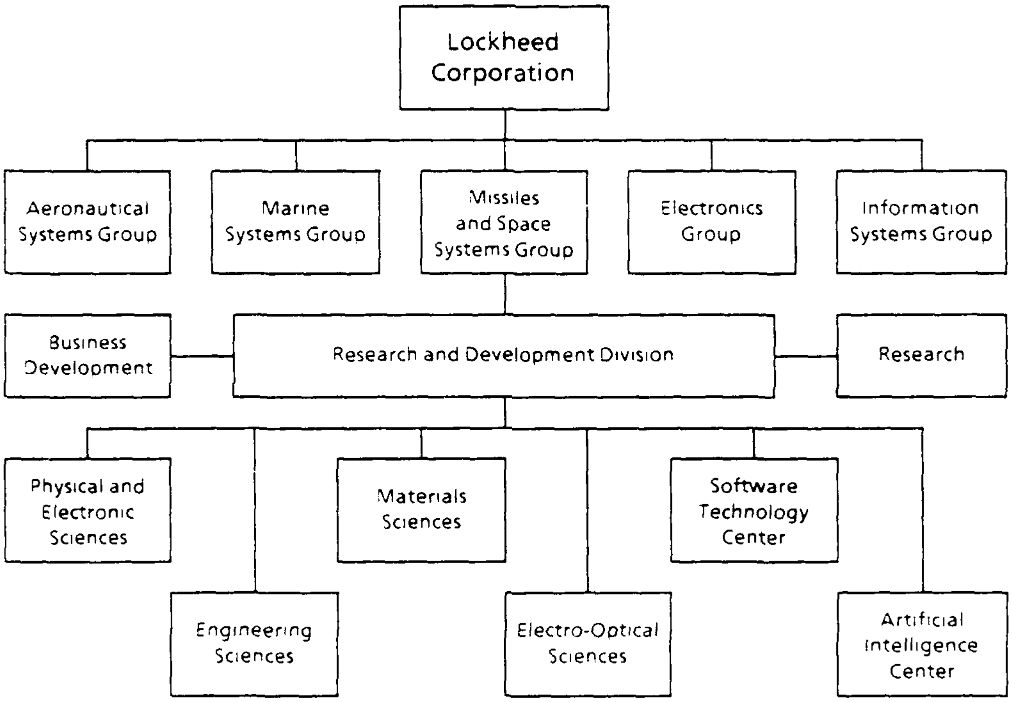


FIG. 2-6. AI WITHIN LOCKHEED's CORPORATE STRUCTURE

The roles of the AIC are quite similar to those of the central AI support activities of all the other companies reviewed herein. Technology transfer including the assimilation of current information on company-wide AI activities and applications, technical consulting, and the identification of key business requirements or problems to which the technology can be advantageously applied are necessary activities for all of the companies' successful use of the AI technologies. Training and education are also necessary and important activities.

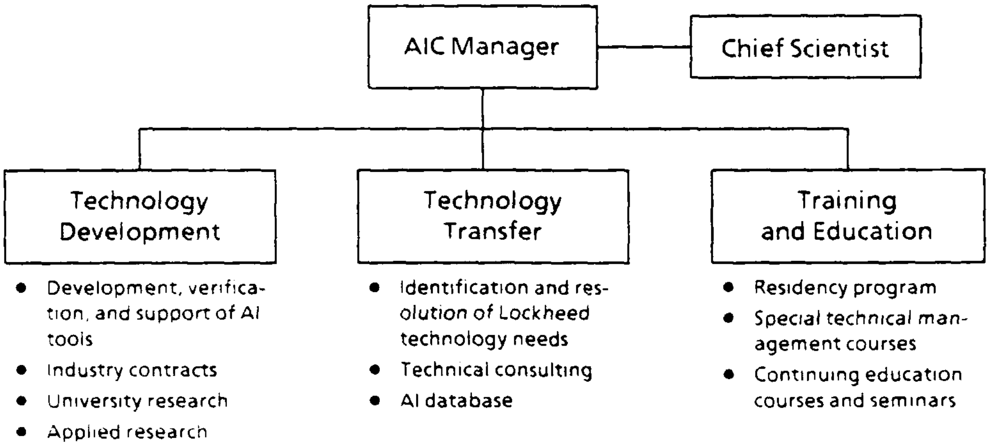


FIG. 2-7. LOCKHEED AIC ORGANIZATION

Lockheed also plays an active role in technology development. It maintains close ties with university AI researchers. In addition, other contractors' services are used, when appropriate. Lockheed also invests heavily in applied AI research, including tool development.

Lockheed has a comprehensive corporate AI education and training program. It includes a management education program, a continuing education program, and a residency program. The 6-month residency program is depicted in Figure 2-8.

Ford Motor Company

Ford formally got involved in AI in the early 1980s, realizing that a number of its major business problems were amenable to AI. One of its first systems was the Service Bay Diagnostician, which was to be used by Ford's automotive dealers to assist their maintenance personnel with car repairs. Ford felt a need for the system in the face of the increasing complexity of its vehicles and the high turnover of maintenance personnel. The goal of the Service Bay Diagnostic System was to use the expert system to guide the mechanic through the vehicle repair process. The expert system used data collected from the vehicle's on-board computers and also queried the mechanic for input.

In 1984, Ford Motor Company purchased equity in both Inference Corporation and the Carnegie Group, two leading AI firms. Also as early as 1984, Ford had an unofficial grassroots group, the Ford AI Working Group, serving the needs of AI

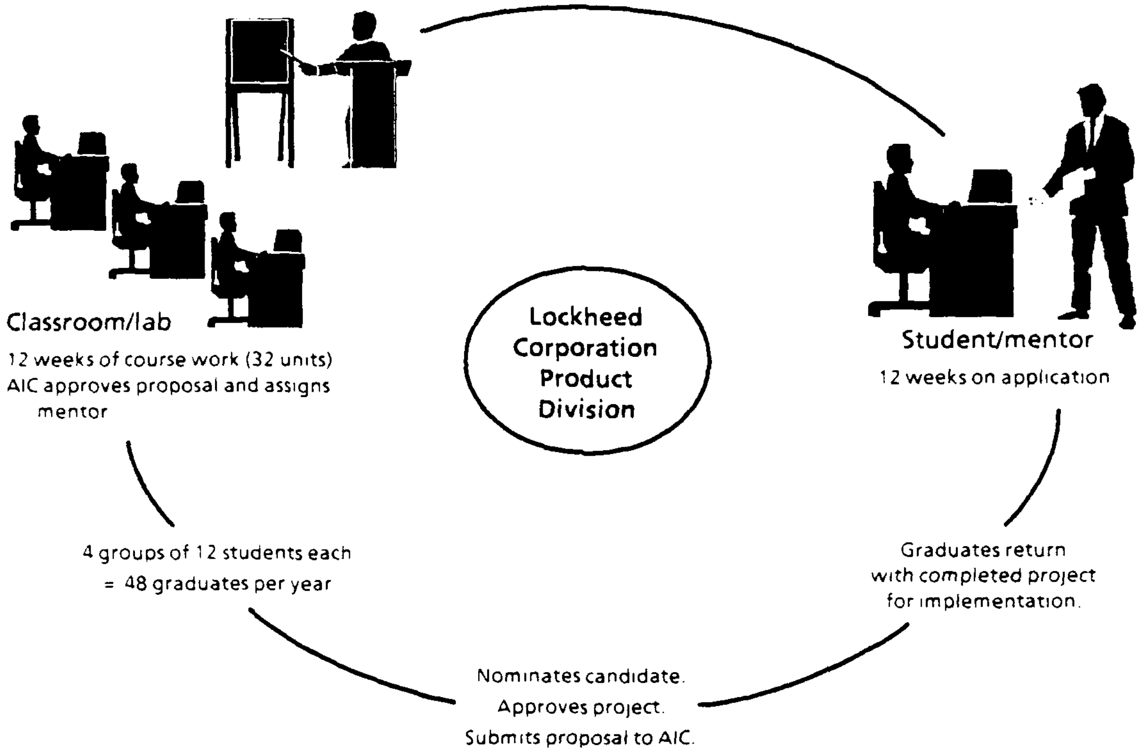


FIG. 2-8. LOCKHEED's AIC RESIDENCY PROGRAM

practitioners. The Ford AI Working Group had no formal support but arose from the need of small groups within the operating divisions to share information and expertise in AI.

Ford is firmly committed to the use of rule-based expert systems for the diagnostics of robotic systems used in its manufacturing operations. The robotics group at Ford Motor Company funded a pilot project to diagnose robot malfunctions, and the project proved quite successful. Ford then notified its robotics suppliers that Ford would only purchase robotic systems from vendors who offered accompanying diagnostic expert systems. For those robotic manufacturers who did not have expert systems capabilities in-house, Ford recommended companies that can develop the expert systems.

The funding of the robot diagnostic expert system pilot is being used as a technology transition model within Ford. A similar project is now under way at Ford Aerospace's Sunnyvale, California, division to develop a diagnostic expert system for a laser-guided welder. Ford is again funding the development of the pilot system.

Once successful, the pilot system will determine the specifications for the operational expert system to be delivered by the manufacturers. The manufacturer of the laser-guided welding system must develop the ability to deliver future expert systems that meet these specifications [19].

Expert Systems have also been used at Ford for functions that range from credit approval to product design. These applications have been developed both under contract and organically. To support their organic development, Ford Aerospace developed a model-based reasoning tool called Paragon.

In early 1986, Dr. Tony Tether, Vice President of Technology and Advanced Development for Ford Aerospace, directed the formation of an AI consortium to be composed of senior members of Ford Aerospace's operating entities. The purpose of the AI consortium was to elevate technology evaluation within Ford Aerospace. The consortium was tasked to formulate a business planning document for the application and cooperative use and development of AI technologies within Ford. The initiative received high-level support from Mr. John Betti, Ford Motor Company's former Vice President of Diversified Products Operations and now Under Secretary of Defense for Acquisition.

Today, the AI consortium continues to meet and is responsible for AI business planning and research coordination. The AI Working Group continues to provide communication and technology transfer functions. However, all technology development is done in support of the business plan. AI research is funded by Government contracts and applications development is funded by Ford's internal clients [20].

General Motors

GM's participation in AI technologies predates its current embodiment within its Advanced Engineering Staff (AES). General Motors Research (GMR) Laboratories started robotics work in the early 1970s, and by the late 1970s GM's Manufacturing Staff, part of Manufacturing, Engineering and Development, was using robotics. The first corporate-wide robotics symposium with talks, exhibits, and application demonstrations occurred around 1980. GMR also initiated GM's effort in machine vision/perception in the late 1960s and early 1970s. The effort was less "mature" than the level of robotics occurring at the same time. By the mid-1970s, Delco Electronics was using a machine vision application to look at integrated-circuit

chip orientation. Other machine vision applications were developed for operating divisions jointly with GMR [21].

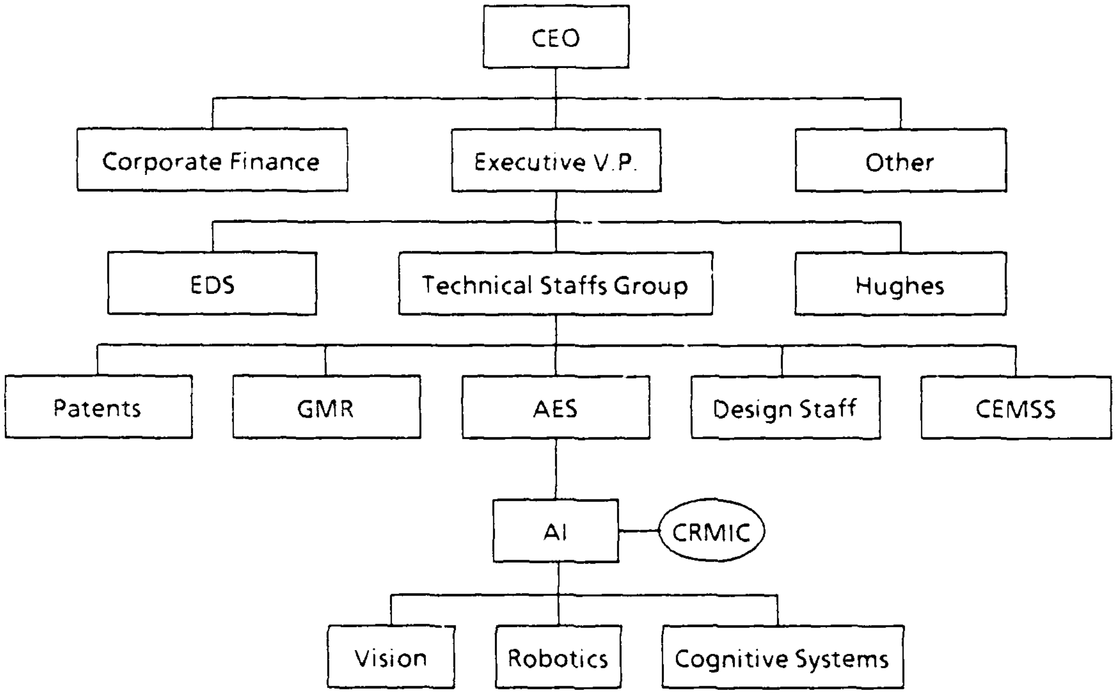
Around 1985 – 86 AES started a natural language processing group. Tools were available, but the vendors were not ready to develop applications in order to leverage the technology. In addition, the Advanced Manufacturing Staff and then later the AI group did some development in voice synthesis and voice processing. In 1985 an expert systems group was added to AES's Machine Intelligence Technology Implementation group and the name was changed to the Artificial Intelligence (AI) group. The Machine Intelligence group and the AI group were combined at about the same time in late 1985 or early 1986. In 1986 restructuring and the addition of natural language technologies and robotics to AI gave rise to the current structure of three groups within the AI group: Vision, Robotics, and Cognitive Systems (containing knowledge-based and expert systems and natural language technologies).

As depicted in Figure 2-9, the GM AI group is a part of AES, which in turn reports to the Technical Staffs Group (TSG) and its group Vice President. The TSG oversees Patents, GMR, the Design Staff, the Current Engineering and Manufacturing Services Staff (CEMSS), and AES. TSG's group Vice President reports to an Executive Vice President (or a Vice Chairman) who also oversee Electronic Data Systems (EDS) and Hughes in addition to TSG. The Executive Vice President reports directly to the CEO.

The Corporate Robotics and Machine Intelligence Council, an adjunct to the AI group, is made up of divisional representatives and meets monthly to solve problems and share information and ideas.

The AI group at GM does a "technology push." Divisions decide what they will incorporate. Usually, additions are small, point implementations. Occasionally, for example, with the addition of a new plant, bigger implementations are planned. AES works to transfer technology, not direct technology.

AES has three objectives in technology transfer: to discover and develop new technology, to deploy that new technology, and to transfer new technology to the divisions. Technology transfer proposes to impart an understanding for the purpose of proliferation and maintenance throughout GM. For example, Packard Electric was the first to use machine vision from the AI group; since then, it has installed



Note: EDS = Electronic Data Systems; CRMIC = Corporate Robotics and Machine Intelligence Council.

FIG. 2-9. GENERAL MOTORS CORPORATION

more than 100 machine vision systems. AES may provide seed money, but the division has to pick up the application after that.

GM's corporate environment is an order of magnitude greater than, say, DEC's. A GM division alone may be equal in size to all of DEC. Therefore, only a few applications have the broad applicability that warrants central support. Spot-welding is one positive example with broad applicability.

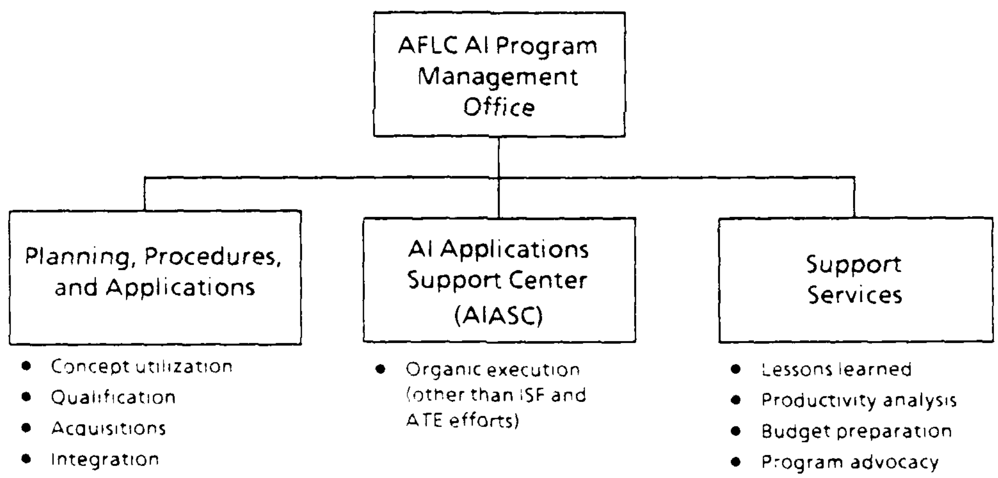
AES tracks and communicates lessons learned. Every installation is recorded in an applications database. Communication occurs in the monthly Corporate Robotics and Machine Intelligence Council (CRMIC) meetings and the annual Manufacturing Technology Conference. AI is also frequently featured in GM's internal publications.

CURRENT DoD AI LOGISTICS INITIATIVES

Within the production and logistics disciplines, DoD Components have been working, for the most part separately, to apply AI techniques. The Army is

developing AI applications at several AI applications centers. One such Army Logistics AI Applications Center is located at Fort Lee, Virginia; additional logistics applications are being developed by the Army AI Center in The Pentagon, by the Army AI Training Center at Fort Gordon, Georgia, and by the Materiel Readiness Support Activity.

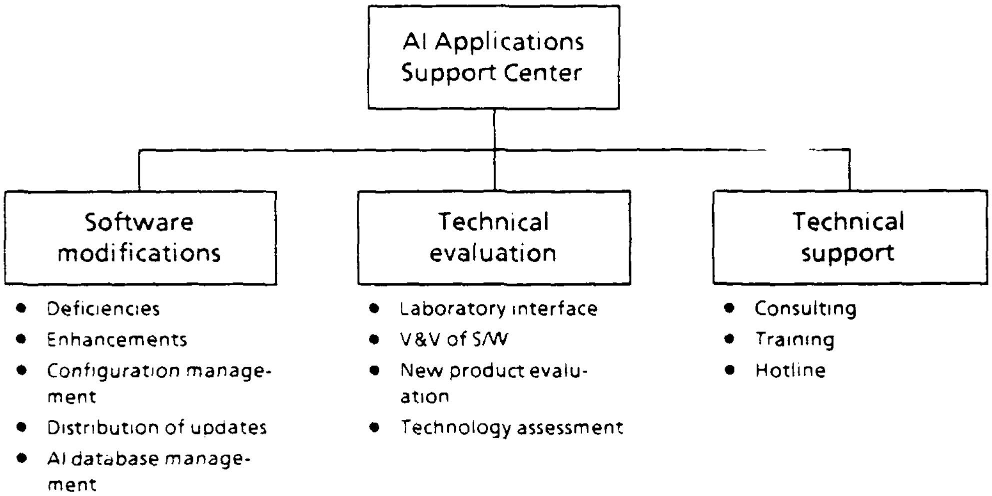
The Air Force has established an AI Program Management Office at the AFLC Headquarters at Wright Patterson Air Force Base (AFB), Ohio. The office currently has more than 20 staff members. The AFLC AI PMO is organized as shown in Figures 2-10 and 2-11. A 1987 study of lessons learned by Fortune 500 companies in developing and fielding AI systems [22] served as the basis for the AFLC AI PMO organizational structure and functions. Figures 2-10 and 2-11 depict the range of services provided by this central organization. Note that many of the functions of the Planning, Procedures, and Applications Branch involve policy determination and guidance.



Note: ATE = Automatic Test Equipment; ISF = Integrated Support Facility

FIG. 2-10. AFLC AI PROGRAM MANAGEMENT OFFICE

The AFLC AI PMO was to be a temporary management organization tasked with ensuring awareness of AI throughout AFLC and providing for the successful transition of the technology via successful fielded applications. The AFLC AI Applications Support Center (AIASC), however, was given a permanent mandate. The two organizations, AI PMO and AIASC, were purposely collocated to ke p scarce



Note: V&V = verification and validation; S/W = software

FIG. 2-11. AFLC AI APPLICATIONS SUPPORT CENTER

AI talent together. As depicted in Figure 2-11, the AIASC was responsible for technical development, evaluation, and support activities.

Development activity in AFLC is dispersed throughout the Command. AI systems development occurs at subordinate field activities and also within the AIASC. In addition, AFLC contracts for the development of large complex AI systems or systems that must be integrated with existing information and decision support systems. Numerous other centers of excellence in AI throughout the Air Force are also exploring logistics AI applications. Those centers include the Human Resources Laboratory, the Air Force Institute of Technology, the Rome Air Development Center, the Strategic Air Command, the Military Airlift Command, and the Air Force's Small Computer Systems Center at Gunter AFB, Alabama.

The Navy is also pursuing logistics AI initiatives and also has numerous centers of excellence including the Navy AI Laboratory in Washington, D.C., the Naval Avionics Center, and the Navy Supply Systems Command. The Navy has pursued the development of several systems through the Small Business Innovative Research Program.

The Defense Logistics Agency (DLA) has established a small central group of four individuals at the DLA Systems Automation Center (DSAC). That group supports others throughout DLA who are attempting to apply AI technologies. DLA

has also started an active DLA AI Working Group and begun management awareness training. Some training is conducted organically, while other training services have been contracted. The Marine Corps and OSD staff activities are also actively investigating AI logistics applications.

Attempts to coordinate the Services' activities have begun. In 1986, the Logistics AI Coordinating Cell (LAICC) was chartered by the Conference of the Logistics Directors (COLD). The LAICC was tasked to foster open communications between the Services and DoD agencies on AI logistics projects. The LAICC is chaired by a representative of the Office of the Assistant Secretary of Defense (Production and Logistics) [OASD(P&L)] and includes representatives from the Director for Studies, Concepts and Analysis, JCS (J4); and the Offices of the Deputy Chief of Staff for Logistics, U.S. Army; the Deputy Chief of Naval Operations (Logistics); the Deputy Chief of Staff Logistics and Engineering, Air Force; the Deputy Chief of Staff Installation and Logistics, Marine Corps; the Office of the Director, Defense Logistics Agency, and the Director, Strategic Defense Initiative Organization.

Each year since 1987, the LAICC, together with the J4 Logistics Directorate and the American Defense Preparedness Association, has sponsored an annual Symposium and Workshop on Artificial Intelligence Applications for Military Logistics at Williamsburg, Virginia. The conference allows the exchange of information among the Services on their AI logistics activities.

In addition, P&L and the LAICC have actively pursued Productivity Enhancing Capital Investment (PECI) funding for logistics AI initiatives. In May 1988, the AI production and logistics applications program was certified as a priority candidate for PECI funds. The LAICC worked with the Services to rank order projects submitted for funding. Fifty-three FY90 projects valued at $26.3 million were approved for all of the Services. Ten FY91 projects valued at $5.3 million have also been approved.

SUMMARY OF INDUSTRY AND DoD AI INITIATIVES AND PHILOSOPHIES

The preceding review of companies, Services, and DoD agencies reveals a number of similarities among the functions or activities required to support the organization's involvement with the AI technologies. Recurrent themes include a requirement to pursue AI as a technique capable of addressing key business needs. The logistics needs, not the technologies, provide the focus. Because the focus is on

the business requirement and because the technologies are viewed as providing key strategic and competitive advantages, senior corporate involvement is viewed as essential in providing strategic direction and resources in the use of the technologies as well as in providing policy guidance. Several companies formalize this activity in groups reporting directly to the company's senior officers. AI Boards of Directors and AI Steering Groups are common within industry.

Another recurrent theme is the important role played by the domain experts in the development and maintenance of these systems. Further, specific roles are performed by all levels of management throughout the company or organization, necessitating that all be aware of the technologies and their capabilities and limitations. Training at all levels of management is suggested; however, emphasis is placed on providing knowledge engineering and knowledge acquisition skills to domain practitioners to permit them to better relate functional information and knowledge system requirements to systems development personnel.

All the companies and organizations examined pursued both centralized and decentralized activities and, both large and small, simple and complex AI systems development initiatives. Figure 2-12 provides a framework for examining and appropriately placing an organization's AI application activities. The discussion of both DEC's and Du Pont's AI activities demonstrated how companies "differentiate" the technology by working on small systems that demonstrate the feasibility of the technology early on. As the company gains an understanding and acceptance of AI technologies over time and builds "critical mass," the philosophy of "differentiation" gives way to a philosophy of "integration." Here, larger, more sophisticated systems tend to be built which combine knowledge from multi-functional areas and integrate AI technologies with other appropriate conventional systems and decision support techniques.

Another recurrent theme is the need for a central group to provide technical consulting and information services. The most common form of information service is an applications database. Technical consulting services include problem selection consulting and education and training services.

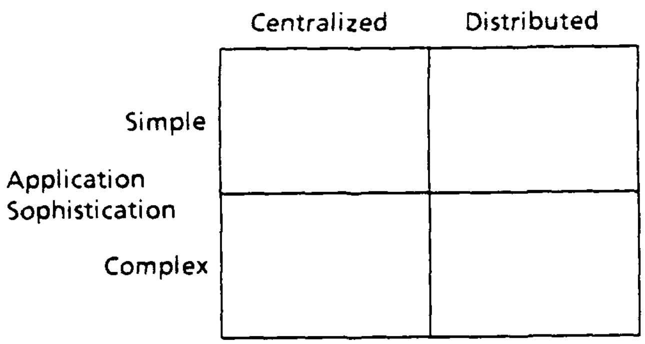


FIG. 2-12. APPLICATION ACTIVITY

CHAPTER 3

A DoD LOGISTICS ARTIFICIAL INTELLIGENCE PROGRAM

THE NEED FOR AN AI LOGISTICS PROGRAM

The ASD(P&L) should move quickly to take advantage of AI applications that the private sector has demonstrated to generate logistics productivity and quality improvements in the range of 5 to 25 percent. DoD is already operating with direction from the White House to achieve a 3 percent annual productivity increase. On 27 April 1988, Executive Order 12637 set a Government-wide 3 percent productivity improvement goal for appropriate functions. The DoD FY90 Productivity Improvement Plan is currently the major tool for achieving that goal. The program contains 63 AI initiatives in DoD functions and programs valued at approximately $31.6 million over FY90 and FY91. Furthermore, DoD is implementing the philosophy of Total Quality Management (TQM) as a prime means to increase productivity through continuous, incremental improvement in quality.

> The objective of DoD management is to make the best use of national defense resources to provide the means to preserve our national security in peace and in war. This is a challenge of significant magnitude. The Department employs one million civilians and two million active duty military personnel, manages 1,200 installations spread around the globe, and for FY90 is submitting a budget that would give it the authority to spend $293.8 billion. DoD executes more than 15 million contract actions each year. Last year, (FY89), the total value of those contracts reached $160 billion [23].

The commercial sector is actively pursuing logistics applications of AI and has established management structures to facilitate these applications, as discussed in Chapter 2. In addition, a recently published report about trends in highly progressive and successful commercial logistics firms indicates that those firms are actively pursuing AI and knowledge-based systems. More than one-fifth of the manufacturers responding indicated plans to install logistics AI applications. Leading edge wholesalers and retailers also had plans to apply AI technologies to logistics [24].

Although AI technologies provide significant increases in weapon systems' operational capabilities, the technologies offer their greatest potential in terms of

improving the effectiveness, efficiency, and quality of DoD's logistics operations and management. These systems contain DoD's most valuable resource – the knowledge of how to successfully plan, budget, and manage the support of our forces. Because they enable us to capture, enhance, and reuse our knowledge of DoD logistics, they represent a strategic technology that should be properly leveraged and controlled. For example, these systems can ensure consistent logistics policy is implemented by all branches of the Armed Forces. Naturally, we must ensure the policy, i.e., knowledge, contained in these systems, is correct and timely.

We recommend that the DoD establish a formal program to accelerate the implementation of AI technologies within production and logistics activities. The program should encompass the following DoD functions: procurement, manufacturing, logistics, and environment and facilities management. The DoD Components affected should be OSD, the Military Departments, Defense agencies, and the JCS.

OBJECTIVES OF THE AI PROGRAM FOR DoD PRODUCTION AND LOGISTICS ACTIVITIES

The objectives of the P&L AI program and logistics-related activities should be to promote the innovative use of AI technologies in DoD logistics; to improve the quality, timeliness, and uniformity of logistics decision making; to increase productivity in the work force; and to reduce the cost of ownership of DoD systems. The Military Departments, DLA, and their field activities should retain program management control over all AI projects. However, they should be obligated to share program information, technology applications, and their lessons learned and assessment of the results with all other DoD elements.

REQUIRED SERVICES FOR A SUCCESSFUL LOGISTICS AI PROGRAM

Based upon a review of corporate and DoD AI initiatives, we developed a tentative list of the services required to enable and support successful AI applications. This list was further refined through extensive interviews with users to determine their needs and desires. Both sophisticated AI developers and novices throughout the Military Departments and Defense agencies were surveyed to determine the services that they would like to see made available to support their AI activities.

This user requirements survey confirmed that organizations are consistently interested in having AI informational and technical services available to support their activities. The services they requested are listed below in priority order, with the highest priority first:

- Information
- Technical support
- Technical assessment
- Programming
- Communications
- Management Support
- Methodology.

Table 3-1 depicts each of these services and the specific functions that each encompasses. Each of these services will be discussed in turn.

Information Services

Our survey indicates that the logistics community needs information services more than any other type of service. As shown in Table 3-1, four primary information service categories were identified during the interview process. All the interviewees mentioned a need for current applications databases and stressed how important it is that those databases contain systems' descriptions that are understandable and do not overuse acronyms. Interviewees also frequently requested information on current tool capabilities, hardware requirements of those tools, and cost information. Numerous individuals suggested a tools database that could be readily accessed. Individuals also requested access to a database of lessons learned on past development efforts. Finally, some persons requested basic reference materials such as current articles and technical reports.

The general consensus is that a great deal of information is available. In fact, this information is literally increasing exponentially on a daily basis. The interviewees need assistance in identifying, filtering, applying, and retaining the available information. The community feels that an organization capable of understanding the technical details and managerial implications of the AI literature

TABLE 3-1

REQUIRED ACTIVITIES FOR A SUCCESSFUL LOGISTICS AI PROGRAM

Service	Function
Information	• Applications database • Tool database • Lessons learned database • Source library
Technical support	• Technical consulting ▸ Problem selection and scoping ▸ Tool selection • AI hotline support • Training and education
Technical assessment	• Applications evaluation and grading • Tools evaluation and new tools evaluation • Technology assessment
Programming	• Systems development • Systems enhancement and maintenance • Systems test and evaluation • Configuration management • Systems documentation
Communications	• Electronic forms • Newsletters • Conferences
Management support	• ROI analyses • Contracting services • Budget preparation • Tool/application distribution
Methodology	• Systems Verification and Validation • Knowledge engineering • Cost/benefit analysis

would serve as a valuable resource. This function would be the same for all Services and DoD agencies.

Technical Support Services

The second most requested service is technical support. In that area, consulting, telephone hotline, and training are the primary categories of interest. Many individuals believe that technical support services are difficult to access. In

many cases, the requirements are not sufficient to warrant contracting for the services, but few alternatives are available. Thousands of users request technical support and only a few qualified organic resources are available to satisfy the demand. The interviewees believe that a Government center could retain and build technical expertise and make it responsive to the manager. Appendix B further addresses the issue of training.

Technical Assessment Services

Technical assessment services include assessing existing AI applications, assessing AI development tools, and assessing maturing laboratory AI technologies. Interviewees would like better information about what applications other DoD organizations are developing to determine whether a particular application might have merit in similar functions within their organizations. Current applications databases contain no information as to how accurate, complete, well-documented, and thoroughly tested a system is. If logistics AI systems are to be adapted for use throughout DoD, some assessment standards or confidence rating schema must be developed.

Interviewees also suggested confidence rating schemes for the evaluation of AI development tools. Today, new tools are rapidly entering the marketplace and existing tools are being enhanced. The community believes that a central group tasked with assessing new tool releases and notifying the users of any substantial changes in functionality and performance will be beneficial. Currently, this tasking is performed redundantly by numerous individuals throughout DoD.

In similar fashion, attempts to pull maturing AI technologies out of the laboratory and apply them to logistics activities can result in unnecessary duplication of effort if the same technology evaluation studies are being conducted or contracted by more than one DoD agency. The community believes that the consolidation of these activities in a central group offers a streamlining of AI activity and will permit wider and more thorough investigations of emerging AI technologies than might otherwise be possible.

Programming Services

The fourth most requested service is programming. The specific programming services most frequently requested were applications development and maintenance,

test and evaluation, configuration management, and the development and maintenance of systems documentation. Individuals frequently expressed the idea that some personnel at their locations had experience with specific tools and access to them. However, no information is available to indicate who those experienced personnel are. A central coordination activity with information on what tools are available within the organization and who is skilled in their use is believed to be of value to the community.

Communications Services

The fifth service requested was communications. Specific functions included in this area are electronic bulletin boards, newsletters, and conferences. The consensus is that community integration will serve to increase the awareness of existing capabilities and, hence, reduce the duplication of effort.

Interagency communication today is nindered not only by the absence of means but also by the nonavailability of communications standards. For example, even the language used to describe an AI system, "a prototype," is vague. A RAND document on expert systems [25] refers to four different prototypes and six expert system development phases (see Figure 3-1). The AFLC AI PMO regularly communicates information on the maturity of its logistics AI application projects in terms of four development phases. The only two phases in which common terminology is used between RAND and AFLC are the terms "concept phase" and "development phase." However, the terms as used by AFLC and RAND mean completely different things depending upon whether the project is being tracked by the AFLC AI PMO or by the RAND methodology. As an aside, given the contracted development period of an AI system as compared to the development timeframe of a conventional system, four phases of development are recommended as adequate. Communication mechanisms and terminology should be determined by a control coordination activity.

Management Support Services

Management support services include the functions of performing ROI analyses, contracting for outside services, advocating and justifying budgets for project seed money and the required central support activities, and distributing tools or other training or support aids.

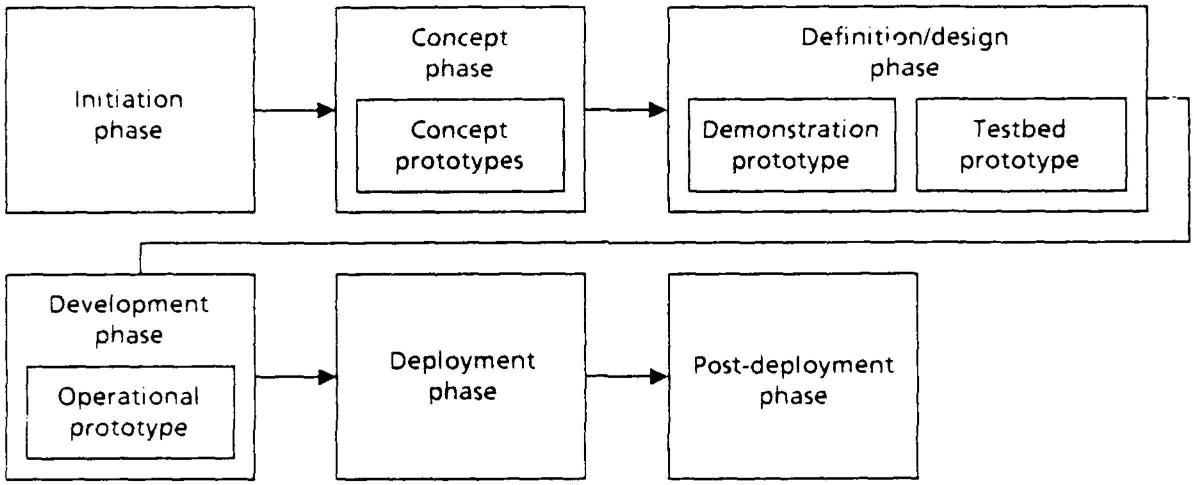


FIG. 3-1. RAND's RECOMMENDED EXPERT SYSTEM DEVELOPMENT PROCESS

Methodology Services

The final service requested by the logistics community during the interview process was in the area of methodologies. Interviewees requested help developing methodologies. The users themselves are prepared to apply the methodologies. However, they believe that they need guidance to indicate which methodologies can be consistently applied in the areas of AI systems verification and validation, knowledge engineering, and the cost/benefit analyses. While the responses in this area were limited, the specific methodologies requested are not well understood within the AI community. The DoD Logistics AI Policy Council should establish guidelines in these areas for use throughout DoD.

OTHER GENERAL REQUIREMENTS

In addition to identifying specific services that the logistics community believes are required to support successful AI initiatives, the interview process also uncovered general opinions about the form and structure of the required functions. In general, users expressed concern that the functions be responsive, on-site or reasonably accessible, and provide for limited "no cost to user" services.

Responsiveness

Most of the individuals interviewed stressed the importance of being able to "turn on" or obtain access to services quickly. For information services, the turn-

around must be nearly instantaneous. For longer term technical support or programming services, the time to initiate the activities must be no more than a few weeks.

Presence

A concern expressed consistently is the ability to deal "personally" with a support specialist knowledgeable in both logistics and AI. Many interviewees believe that some form of on-site presence will result in more responsive service. Further, they believe it is important that their time not be wasted having to explain details of the logistics process to the individual or team that is to provide the support. They believe that the team should already understand the important functions, leverage points, and interactions of the logistics process.

"No Cost to User" Services

Among the most revealing comments are the desires of many individuals to obtain limited forms of support, such as a quick answer to a question about the advisability of using a particular tool for a particular application or the risks of one form of application as compared to another in a different functional area of logistics. Many individuals who wanted to begin applying the technology in their organization expressed concern that funding was not available to support their initiatives. The OSD Logistics AI Policy Council should consider supporting a limited range of services to be provided at no cost to the user. These services would be supported by "core" recurring funding.

RELATED ISSUES

Longevity

The DoD logistics community requires access to a technically and functionally competent and experienced staff. The OSD support function should provide stability and longevity.

Flexibility

While stability and longevity are important, the OSD logistics AI support function must be responsive. The staff should be free to expand and contract gracefully, without having a large expensive core staff to support.

Independence

After speaking with numerous individuals from different organizations across the Military Departments and Defense agencies, we recommend that the OSD Logistics AI support function remain independent of any particular Military Department or agency. That independence will remove any potential for the support activity to be "limited" by association with a particular command or organization. By promoting independence, OSD can ensure all DoD organizations feel the program is supporting their requirements. Further, the Military Departments and Defense agencies require some independence to execute their programs within the guidelines and policy direction outlined by the Secretary of Defense.

Government Managed

While independence is important, it is also important that the logistics AI support activity be directly managed by a government body. This can be accomplished by establishing a government steering group to continuously evaluate the OSD production and logistics AI activities. This recommendation is directed at eliminating any potential for "conflict of interest" that could exist if the DoD logistics AI support activity were contractor managed.

CHAPTER 4

IMPLEMENTATION OF THE DoD ARTIFICIAL INTELLIGENCE LOGISTICS PROGRAM

ORGANIZATIONAL ISSUES

One of the key lessons learned by U.S. industry during the past decade in its attempts to apply AI technologies is the importance of establishing activities dedicated to ensuring the organization approaches and applies the technologies appropriately to realize the highest leverage to the mission. Policy guidance and direction must be established and should be provided by the highest levels of management. For example, both DEC and IBM have top executive level oversight committees. In addition, the services discussed in Chapter 3 must be provided.

Based upon a careful analysis of the nature and requirements of the AI technologies, the lessons learned by industry and other organizations, and the support required by the logistics community in applying AI technologies to their functions, we recommend the organizational structure depicted in Figure 4-1 as the best structure to facilitate the rapid implementation of AI technologies within P&L-related activities.

DoD Logistics AI Policy Council

The Department of Defense should establish a Policy Council to determine the specific direction, priorities, and policies of its logistics AI program. The DoD Logistics AI Policy Council should be chaired by the ASD(P&L). The following individuals should be designated as members of the Council:

- Deputy Assistant Secretary of Defense (Logistics) [DASD (L)]
- DASD (Procurement)
- DASD (Production Support)
- DASD (Installations)
- DASD (Environment)

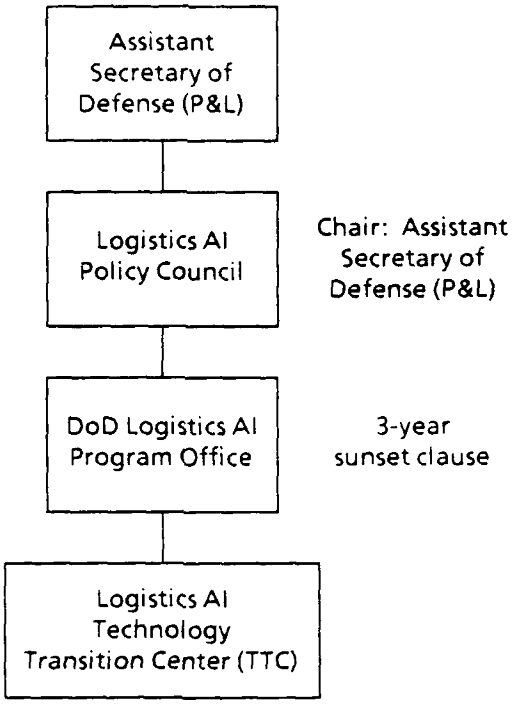


FIG. 4-1. DoD AI LOGISTICS PROGRAM ORGANIZATIONAL STRUCTURE

- DASD (Systems)
- DASD (Management Systems)
- AI Program Manager, Director for Logistics, JCS
- AI Program Manager, United States Air Force
- AI Program Manager, United States Navy
- AI Program Manager, United States Army
- AI Program Manager, United States Marine Corps
- AI Program Manager, Defense Logistics Agency.

DoD Logistics AI Program Office

In addition, the ASD(P&L) should establish a DoD Logistics AI Program Office as a temporary office for approximately 3 years. The DoD Logistics AI Program Office would have a small permanent staff of six that would be supplemented as

necessary by individuals on loan from the Military Departments and Defense agencies. This small Program Office would assist the Logistics AI Policy Council in establishing and implementing policy guidance and direction. It would also help establish a permanent central DoD technical support staff at the Logistics AI Technology Transition Center (TTC).

Specifically, the DoD Logistics AI Program Office would be tasked to perform those management functions necessary for rapidly transferring AI technologies into logistics operating units throughout the DoD Components. The Program Office staff would "differentiate" and push the application of AI technologies in logistics by pursuing an active logistics and AI marketing effort. That effort should be composed of three principal activities: publicity, the distribution of free samples, and presentations to carefully selected key decision makers throughout DoD. The staff should widely publicize successful logistics AI systems and should emphasize the real-world benefits that the systems are generating. The staff should also publish articles in popular logistics journals, including the *Society of Logistics Engineers Spectrum*, the *Military Logistics Forum*, etc. The Program Office should distribute to DoD Components free samples of PC-based, nontrivial AI systems in each functional area of logistics (maintenance, inventory, acquisition, transportation, warehousing, etc.). Finally, the staff should brief key individuals throughout DoD on the DoD Logistics AI Program. The staff should solicit the recommendations of those individuals for improving the OSD initiatives. The Program Office should establish the goal of reaching every logistician in the DoD Components and making them aware of the potential use of AI technologies in logistics before the office is officially disbanded.

Logistics AI Technology Transition Center

A DoD Logistics AI TTC should be established as a permanent central DoD activity. It should be tasked to provide those services previously identified and discussed in Chapter 3 as being required for the successful implementation of an AI program (see Table 3-1).

Analysis of the user requirements data and interviews with those commercial and Federal activities that have successful track records in applying AI indicates two overlapping areas of requirements, as depicted in Table 4-1. These areas are the technical disciplines for which support is required, e.g., expert systems, natural

TABLE 4-1

TECHNOLOGY TRANSITION CENTER SERVICES

Services	Technical disciplines					
	Expert systems	Natural language	Speech	Vision	Intelligent robotics	Neural networks
Information • Applications database • Tool database • Lessons learned database • Source library • Reusable software library						
Technical support • Technical consulting ‣ Problem selection and scoping ‣ Tool selection • AI hotline support • Training and education						
Technical assessment • Application evaluation and grading • Tools evaluation • Technology assessment						
Programming • Systems development • Systems enhancement and maintenance • Systems test and evaluation • Configuration management • Systems documentation						
Communications • User groups • Electronic forums • Newsletters • Conferences						
Management support • ROI analyses • Contracting services • Budget preparation • Cost/benefit marketing						
Methodology • Systems verification & validation • Knowledge engineering • Qualification guidelines						

language, speech, etc., and the specific types of services that are required. Table 4-1 depicts this functional framework in matrix format. This matrix should be used to define and bound the TTC concept.

After reviewing the feedback from the logistics AI community, we examined alternative means of providing these services. One means is the creation of a TTC. That concept has a precedent in the form of the more than 20 chartered DoD Information Analysis Centers (IACs). While each of these centers is dedicated to a particular discipline or mission, none specifically addresses AI or AI and logistics.

An alternative to the creation of a TTC is the establishment of a new IAC. However, IACs typically collect, review, and store available information specific to a specialized technical discipline. They also can provide a network of technical experts to supplement the technical information with consulting in specialized areas [26].

IAC services cover the information services, communications services, and can cover a part of technical support services (technical consulting). However, IACs do not provide the other services and functions required of the TTC (see Table 4-1). Hence, we decided to adapt the IAC concept and recommend a TTC specifically suited to the transfer of AI technologies to logistics.

The TTC can serve as a central DoD-wide activity capable of retaining corporate memory of the DoD Logistics AI Program. Further, it can offer a set of services at no cost to the user. At the same time, the TTC can operate as a separate cost center capable of accepting funding for extended consulting, evaluation, or programming services. For example, a criterion of 20 hours of services might be established. Users would only be charged for a specific project's services that exceed 20 hours of the TTC staff members' time. Thus, the TTC could provide the requested "no cost to the user" services and at the same time maintain basic self-sufficiency. A small recurring budget would be required to support the ongoing activities of the TTC. All of the corporate central AI Application Support Centers examined in Chapter 2 operate as separate cost centers. They are reimbursed by using groups throughout the company.

Creation of a DoD Logistics AI TTC does not preclude either the decentralization of some of these services (e.g., programming) to Military Department "mini-TTCs," nor does it preclude contracting for any of the required services. Successful operation of the TTC, however, does provide valuable services to the user

community and it does preclude unnecessary duplication of effort and the waste of resources.

LOGISTICS AI POLICY ISSUES TO BE RESOLVED

As mentioned throughout this report, a number of critical policy issues must be resolved and policy guidance provided to DoD activities. Table 4-2 summarizes some of those issues. The Logistics AI Policy Council would provide a forum for the discussion and resolution of these difficult issues. Appendices B, C, D, and E provide specific recommendations and frameworks that can be reviewed and used to resolve many of these issues.

TABLE 4-2

AREAS REQUIRING POLICY RESOLUTION

Determination of specifications and standards	• Standard tools/development environment • Terminology/database fields and formats
Acquisition policy	• Contracting methodology • In-house development versus contract
Commitment of resources	
Methodology services	• Systems verification and validation • ROI/LCC analyses • Knowledge engineering • Technology assessment • Tool assessment
Systems development and maintenance	
Application qualification guidelines	
Training curricula	• In-house training versus contract training

Note: LCC = life-cycle cost.

GLOSSARY

ADP	=	Automatic Data Processing
AES	=	Advanced Engineering Staff (GM)
AFB	=	Air Force Base
AFLC	=	Air Force Logistics Command
AI	=	Artificial Intelligence
AIAG	=	Artificial Intelligence Applications Group (DEC)
AIASC	=	Artificial Intelligence Applications Support Center (AFLC)
AIBOD	=	Artificial Intelligence Board of Directors (DEC)
AIC	=	Artificial Intelligence Center (Lockheed)
AIMG	=	Artificial Intelligence Marketing Group (DEC)
AIPG	=	Artificial Intelligence Product Group (DEC)
AI PMO	=	Artificial Intelligence Program Management Office (AFLC)
AIPO	=	Artificial Intelligence Project Office (IBM)
AISC	=	Artificial Intelligence Support Center (IBM)
AITC	=	Artificial Intelligence Technologies Center (DEC)
ASD	=	Assistant Secretary of Defense
ASM	=	Automated Storage Module
ATC	=	Advanced Technology Center (Boeing)
BCS	=	Boeing Computer Services (Boeing)
CALS	=	Computer-Aided Acquisition Logistics Support
CBR	=	Chemical, Biological, Radiological
CDRL	=	Contract Data Requirements List
CEMS	=	Comprehensive Engine Management System

CEMSS	=	Current Engineering and Manufacturing Services Staff (GM)
CEO	=	Chief Executive Officer
COLD	=	Conference of the Logistics Directors
CRLCMP	=	Computer Resources Life Cycle Management Plan
CRMIC	=	Corporate Robotics and Machine Intelligence Council (GM)
CSDG	=	Configuration Systems Development Group (DEC)
DEC	=	Digital Equipment Corporation
DID	=	Data Item Descriptions
DLA	=	Defense Logistics Agency
DMA	=	Dues Management Advisor
DoD	=	Department of Defense
DSAC	=	Defense Logistics Agency Systems Automation Center
EDI	=	Electronic Data Interchange
EDS	=	Electronic Data Systems (GM)
EIA	=	Electronic Industries Association
ES	=	Expert System
FFP	=	Firm Fixed Price
GE	=	General Electric
GFE	=	Government Furnished Equipment
GM	=	General Motors Corporation
GMAC	=	General Motors Acceptance Corporation (GM)
GMR	=	General Motors Research Laboratories (GM)
HOL	=	Higher Order Language
IAC	=	Information Analysis Center
IBM	=	International Business Machines Corporation
ILS	=	Integrated Logistics Support
ILSP	=	Integrated Logistics Support Plan

ISTG	=	Intelligent Systems Technology Group
JCS	=	Joint Chiefs of Staff
KBS	=	Knowledge-Based System
KEE	=	Knowledge Engineering Environment
LAICC	=	Logistics Artificial Intelligence Coordinating Cell
LCC	=	Life-Cycle Cost
LOGPARS	=	Logistics Planning and Requirements Simplification
LSAR	=	Logistics Support Analysis Record
NDI	=	Nondestructive Inspection
OSD	=	Office of the Secretary of Defense
P&L	=	Production & Logistics
PC	=	Personal Computers
PECI	=	Productivity Enhancing Capital Investment
PIF	=	Productivity Investment Funding
PMO	=	Program Management Office
RAMP	=	Rapid Acquisition of Manufactured Parts
ROI	=	Return On Investment
SOW	=	Statement of Work
STL	=	Santa Teresa Program Laboratories (IBM)
TACOM	=	Tank and Automotive Command (Army)
TSG	=	Technical Staffs Group (GM)
TTC	=	Technology Transition Center
TQM	=	Total Quality Management
WIP	=	Work In Process

REFERENCES

[1] Wolf, Stephen M. "Editorial Opinion." *Vis a Vis, New York*, East/West Network, Inc., Jun 1989.

[2] Davis, Randall. *Knowledge-Based Expert Systems: Planning & Implementation*. Addison-Wesley AI Training Video; 1987.

[3] Feigenbaum, P. E., McCorduck, and H. P. Nii. *The Rise of the Expert Company*. Times Books, 1988.

[4] Telephone conversation with Jack Rahaim, Corporate Artificial Intelligence Marketing Manager, and Themis Papageorge, Manager, Strategic Planning and Third Party Programs, Digital Equipment Corporation. 1989.

[5] Barker, Virginia E. and Dennis E. O'Connor. "Expert Systems for Configuration at Digital: XCON and Beyond." *Communications of the ACM*, Vol *32*, No. 3 (Mar 1989).

[6] Telephone conversation with Bruce Martin, Program Manager for Expert Systems, Artificial Intelligence Project Office, International Business Machines, Corp., Jun 1989.

[7] Telephone conversation with Edward Mahler. AI Program Manager, DuPont Co., Wilmington, Delaware. June 1989.

[8] Telephone conversation with Fred Schaeffer, Supervisor, Distribution Operations Research, Eastman Kodak Company. May 1989.

[9] "Point to Point," General Motors internal newsletter, Detroit, Michigan, Jun/Jul 1988.

[10] Telephone conversation with Mark S. Cane, Assistant Vice President, Marketing Resources, Burlington Northern Railroads. Apr 1989.

[11] Carnegie Group, Inc. *Does Your Competition Know Something You Don't?* Addison-Wesley Training Systems Knowledge-Based Systems in Manufacturing Video Training Course.

[12] Personal interview with Mike Niebler, Marketing Representative, Texas Instruments. Feb 1989.

[13] Allen, Mary Kathryn, and Omar K. Helferich. *Putting Expert Systems to Work in Logistics*, publication forthcomin_, Oak Brook, Illinois: Council of Logistics Management, 1989.

[14] Allen, Mary Kathryn. *The Development of an Artificial Intelligence System for Inventory Management*, Oak Brook, Illinois: Council of Logistics Management, 1986.

[15] Jones, David L., Deputy Chief, Traffic Management Operations, Military Traffic Management Command. *Presentation to the 1989 Artificial Intelligence Applications for Military Logistics Symposium*, Williamsburg, Virginia, 29 Mar 1989.

[16] Helferich, Omar K., R.L. Cook, and S. Oaks. "Artificial Intelligence Applications in Inventory Control." *Proceedings of APICS 30th Annual International Conference*, St. Louis, MO, 22 October 1987.

[17] Graver, Jay. "LOGPARS: Logistics Planning and Requirements Simplification System – An ILS Expert System." *Proceedings for the Artificial Intelligence Applications for Military Logistics Symposium and Workshops*, Williamsburg, Virginia, 29–31 Mar 1988.

[18] Grant, Frances. *Lockheed Artificial Intelligence Center*, Menlo Park, California, 1988.

[19] Telephone conversation with Dr. Philip M. Tuchinsky. Principal Research Engineer Associate, Ford Motor Company, Detroit, Michigan. 18 Aug 1989.

[20] Telephone conversation with Marilyn Golden. Manager of Technology Programs and Functional Manager of AI, Ford Aerospace, Sunnyvale, California, 17 Aug 1989.

[21] Telephone conversation with Frank Caiati, Director, Artificial Intelligence Group, Advanced Engineering Staff, General Motors Corporation. Jun 1989.

[22] Boggs, Paul. "A Strategic Plan for Support of Expert Systems in Organizations." Unpublished Master's thesis, Air Force Institute of Technology. DTIC Report Number GLM-LSY87S-6, Sep 1987.

[23] Annual Report of the Secretary of Defense to Congress from Frank C., Carlucci, U.S. Government Printing Office, Washington, D.C. 17 Jan 1989.

[24] Bowersox, Donald J. *Leading Edge Logistics: Competitive Positioning for the 1990s*, Oak Brook, Illinois: Council of Logistics Management. 1989. p. 167.

[25] Kameny, Iris, Umar Khan, Jody Paul, and David Taylor. *Guide for the Management of Expert Systems Development*. RAND Working Draft Document Number WD-3988-P&L. Jun 1988, Santa Clara, California.

[26] DoD Information Analysis Centers Directory. Defense Technical Information Center, Mar 1988.

BIBLIOGRAPHY

"Digital Equipment Corp. Saves Millions with Expert Systems!" *Expert Systems Strategies, 3: 8*. Harmon, Paul, ed. Cutter Information Corp. 1987.

Lynch, Frank, Charles Marshall, Dennis O'Connor, and Mike Kiskiel, II. "AI in Manufacturing at Digital." *The AI Magazine*, Winter 1986.

Telephone conversation with Candice Matteucci, Staff Systems Analyst, Artificial Intelligence Support Center, International Business Machines Corporation. Jun 1989.

The Boeing Company Annual Report, 1988, p. 4 – 22.

Telephone conversation with Steve Yanagimachi, Project Manager, Center for Artificial Intelligence, Boeing Corp., Jun 1989.

Telephone conversation with Perry Thorndyke, Strategic Applications Program Manager, FMC Corp., Jun 1989.

Yourdan and Constantine. *Structured Design*, Prentice-Hall, 1979.

DoD Directive 3200.12-R. *Centers for Analysis of Scientific and Technical Information Regulation*. Jan 1985.

McDermott, John. "R1: The Formative Years." *AI Magazine*, Summer 1981.

Personal communication with Raymond Muzzy, Business Development Director, Artificial Intelligence Center, Lockheed Missile and Space Company. May 1989.

"That Maintenance Iceberg," *EDP Analyzer*, Vol 10, No.10 (Oct 1972).

Williamson, Mickey. "At Du Pont, Expert Systems Are Key to AI Implementation," *PC Week*, 13 Jan 1987.

Telephone conversation with Marilyn Golden. Manager of Technology Programs and Functional Manager of AI, Ford Aerospace, Sunnyvale, California. 17 August 1989.

Telephone conversation with Dr. Philip M. Tuchinsky. Principal Research Engineer Associate, Ford Motor Company, Detroit, Michigan. 18 Aug 1989.

APPENDIX A

CORPORATE ORGANIZATIONS APPLYING ARTIFICIAL INTELLIGENCE

DIGITAL EQUIPMENT CORPORATION

Digital Equipment Corporation (DEC) is a computer manufacturing company whose product is a complex mix of hardware and software configured to meet an individual customer's needs. DEC's marketing distinctiveness comes from the flexibility it allows its customers in component selection. Rather than marketing standard systems with a limited number of options, DEC markets customer-tailored systems. It believes that this a la carte, build-to-order marketing strategy for big computer systems is a competitive advantage. Hardware and software configuration is at the core of this strategy. The product line consists of 42 different families of central processor types and their peripherals and software.

DEC got its start in artificial intelligence (AI) because of a very important business problem that had senior management recognition and resolution support. Configuring a computer system tailored to a customer's need is a time-consuming and error-prone activity that is dependent on the talent and skill of an experienced configurator. Since such talent is rare and expensive, DEC decided to develop an expert system configurator in order to maintain its build-to-order marketing strategy [A-1 and A-2].

The corporate culture in DEC's manufacturing operations is open to change and new ideas and technologies that will help it in its corporate mission. Carrying ideas across functional boundaries is an acceptable and encouraged practice. Consequently, it obtained its initial AI expertise through university channels with discretionary funds, under the sponsorship of a group engineering manager and the Vice President of Research [A-3]. DEC hired John McDermott, a professor at Carnegie-Mellon University, to develop a configuration expert system prototype, called R1, for the VAX 11/780 computer [A-3 and A-4]. After this successful proof-of-concept, the management issues became how to integrate R1 with as little disruption as possible, and how to establish a group able to continue developing and extending

R1 [A-4]. With the sponsorship of the Vice President of Manufacturing and the Vice President of U.S. Manufacturing, the Configuration Systems Development Group (CSDG) was established in 1980 [A-2].

The first DEC corporate-sponsored AI training, support, and apprenticeship programs were taught by the CSDG and paid for by Manufacturing. In 1984, the Artificial Intelligence Technologies Center (AITC) was formed. Initially, it reported to Manufacturing. Early coordination and planning across functional groups was informal, a product of DEC's corporate culture. Recently, coordination needed to tackle the configuration issues has been formalized in a Configuration Systems Steering Committee of managers of strategically selected business constituencies [A-2].

The AITC is no longer in the Manufacturing function but instead reports to the Artificial Intelligence Board of Directors (AIBOD), chaired by the DEC Vice President of Networks and Distributed Systems Group and composed of Vice Presidents from Engineering, Marketing, Manufacturing, Software Services, and Field Services. The AIBOD reports to the Senior Vice President in charge of all product-related operations, who in turn reports directly to the Chief Executive Officer (CEO). The mandate for the AITC is permanent [A-2].

The AITC has four groups: The Intelligent Systems Technology Group (ISTG) develops and maintains DEC's internal applications; the Artificial Intelligence Applications Group (AIAG) consists of developers of internal diagnostic applications for DEC field service organizations; the Artificial Intelligence Product Group (AIPG) includes the people responsible for selling DEC's AI products (VAX Lisp, VAX OPS5, and the AI VAXStation); and the Artificial Intelligence Marketing Group (AIMG) markets DEC's AI hardware, AI software, and AI consulting and training services [A-5].

The AITC is further integrated with the rest of DEC's organization via a matrix of reporting responsibilities. Selected individuals in various business constituencies (Engineering, Manufacturing, Field Service, Software Services, Personnel, Marketing, and Finance) also report directly to the Manager of AITC. For example, Ms. Virginia Barker is Manager of CSDG in Manufacturing and as such reports to the Vice President of Manufacturing. She is also in the ISTG part of the AITC, and

reports to the Manager of the AITC. (Recall that the Vice Presidents of many of these business constituencies also sit on the AIBOD.) [A-2]

The distribution of AI tasks at DEC is both centralized and distributed. The Intelligent Systems Technology Group, the AI Applications Group, the AI Product Group, and the AI Marketing Group have all been collected under the AITC [A-5]. Thus, AI engineering development, validation, and disbursement; hardware and software selection; and external marketing functions are centralized. Knowledge engineering activities, maintenance of production systems, and some forms of applications support are line-function responsibilities [A-2].

Training is conducted at the AITC in Marlboro, MA. DEC business units pay for personnel and materials and supply the domain and integration expertise – the AITC with more than 200 people is a cost center [A-5]. Application selection expertise is supplied by the AITC. Applications support is organic, coming from either line-function personnel or the AITC [A-2]. Worldwide, DEC has approximately 500 people working in AI, half of them in line-functions on internal projects [A-2].

Program payback has not been rigorously measured. A general estimate is $100 million per year [A-2]. DEC's AI efforts in configuration have allowed the corporation to maintain a marketing strategy that handles increasing product complexity and preserves customer choice.

The experience has had an unexpected payback in its effect on DEC's strategic view of its business. The process has given rise to the knowledge network vision based on the idea of the "knowledge network." The knowledge network is "the everyday problem-solving activity within the organization (that) can be thought of as conducted by a network of experts knowledgeable about the products and the physical and paperwork processes that constitute the business" [A-6]. Within the knowledge network are "pockets of expertise" with decision-making know-how and undocumented expertise. These "pockets of expertise" are order administration, engineering, planning, manufacturing, production, distribution, marketing and sales, customer-field support, and the customer. Point solutions fail to make this connection and miss this higher level of integration.

Two major business cycles appear within DEC's knowledge network – the order-process cycle and the product life cycle. The order-process cycle involves

product requirements, specifications and design, intelligent manufacturing, and order logistics such as scheduling and sourcing. The product life cycle involves developing product requirements, transitioning into manufacturing, planning the manufacturing process, and managing projects.

The knowledge network vision has led to the development of these order-process cycle expert systems: XCON is used to validate the configurability of customer orders and to guide actua assembly of these orders. XSEL is used interactively to assist in the selection of the saleable parts that make up a customer's order. XFL is used to diagram a computer room floor layout for the configuration under consideration. XCLUSTER is used to assist in configuring clusters (DEC sells its VAX computer line in resource-sharing clusters of central processing units). XNET is an expert system that will design and configure local area networks. The knowledge network vision has led to the development of these product life-cycle expert systems: SIZER is a research effort in customer computer resource planning. RIME is a software engineering methodology to enable the more effective building of new configuration expert systems [A-6]. The knowledge network vision fosters the mechanisms for cross-functional communication and feedback. The payback to DEC includes manufacturing process efficiencies, specification change enablement, evolution to future processes, and a testbed for software product technologies.

The first big lesson for DEC is that it needs a critical mass of expertise. As pointed out, the AITC has more than 200 members at its Marlboro location. Its activities center around DEC's needs with AI: manufacturing and engineering applications, AI product development (VAXLisp, VAX OPS5, AI VAXStation), and marketing of DEC AI products and services. The second lesson for DEC is that it needs a mechanism to transfer the technologies into the business units [A-2].

INTERNATIONAL BUSINESS MACHINES CORPORATION

International Business Machines (IBM) is one of the world's largest corporations. Its business involves every area of advanced technology in information processing, from semiconductors to superconductors. Research and development and product-related engineering efforts cost more than $5 billion a year (IBM Innovation, July 1987).

In 1985, a report to the Corporate Management Committee declared that AI was mature enough for IBM, and recommended that the company establish a small,

high-level group with access to top management to coordinate IBM's application of the technologies. Following that recommendation, IBM made a top-level management decision to use AI in 1985. Its Corporate Management Committee, comprised of the CEO, Chairman of the Board, and several Vice Presidents, tasked the Vice President of the Systems Research Division to head the effort [A-3]. The Vice President of Systems established the Artificial Intelligence Steering Committee as part of the Corporate Management Board. The Corporate Management Board is made up of approximately 25 senior level corporate officers and reports to the Corporate Management Committee. At the recommendation of the Vice President of Systems Research Division, the Management Committee created the Artificial Intelligence Project Office (AIPO) [A-7].

Before 1985, IBM made some effort to apply AI to existing problems. One of the first tasks of the IBM AIPO was to listen to what the line-functions were doing in AI. The Project Office's objectives were to solidify IBM's project plan for expert systems, to make IBM's marketing of expert systems a relative success in the United States and worldwide, and to develop an internal AI use program.

The Project Office was established as a temporary organization and officially disbanded at the end of June 1989. The office was intentionally small. Only 14 persons provided top-level strategic coordination. The Project Office was part of Enterprise Systems reporting directly to the Corporate Management Board.

The AIPO successfully imbued IBM's infrastructure with the ability to distribute skills to support expert systems development and fielding. The two major thrusts were technology transfer and distributed development [A-7]. The office succeeded in part by providing seed money for strategic projects. Ongoing responsibilities for technology and AI technology transfer have now been transferred to Programming Systems. Ongoing responsibilities for AI policy have been transferred to Corporate Information Systems.

The AISC actually predates the AIPO and is part of the Programming Systems line-of-business. As part of the Santa Teresa Program Laboratories (STL), the AISC was physically moved in 1986 to STL's Palo Alto Research Laboratories to be close to the Menlo Park Development Laboratories where knowledge-based systems (KBS) development under STL is located. AISC's mission is to provide KBS application support for all IBM operating units [A-8]. AISC programs include application

support of grass roots projects in the form of consultation and collaborative projects; KBS education, from fundamentals to advanced functions, and executive and technical trainings; information exchange and lessons learned through an internal use database, site support groups, and site user groups; technology support in tools and languages; and advanced technical enhancements (image, speech, etc.).

AISC uses the AI Internal Use Council to internally market AI technologies to IBM's lines-of-business and communicate success stories. This marketing effort is part of the attempt to distribute the technology. AISC's objective is to establish centers of competency within IBM's lines-of-business.

Between an estimated 600 and 800 internal customers are actively developing projects. Excluding marketing and research, 13 locations and 75 to 100 individuals provide some kind of support for the internal use of AI within IBM worldwide. Corporate Information Services takes the policy-making position vacated by the termination of the AIPO and will determine future corporate policy for IBM internal use.

The estimated return for commercial operations is greater than $50 million per year. From the strategic view, the AIPO's objectives are a consistent and worldwide marketing of AI technologies and a coherent product (expert systems tools) line. Also, from a market point of view, positioning the company to enable product evolution from high-volume data processing into intelligent data processing products (from automation of back office functions to automation of front office functions) is a principal benefit [A-7].

BOEING CORPORATION

Boeing's business encompasses the engineering, design and manufacturing of airplanes, helicopters, aerospace technologies, and commercial and military avionics. In 1988, Boeing Commercial Aircraft delivered 290 jet transports and 337 other commuter aircraft. Boeing Computer Services (BCS) is an integrator of large-scale, complex information and telecommunications systems, with broad activities in information and telecommunications technologies [A-9].

Boeing entered into AI in response to external research and development requests for proposals from the Government. Projects within Boeing are related to each division's business needs. The Center for AI is in the Advanced Technology

Center (ATC) for Computer Sciences (formerly the Advanced Technology Applications Division) of BCS [A-10].

During the startup phase, the ATC conducted all AI training, including everything from beginning courses in AI to graduate-level course work. The ATC would take a problem domain and line-function personnel and work in a consulting relationship until the line-function personnel could take a solution back to the home division. The ATC handled both training and technology transfer into the divisions.

Subsequently, training has been transferred into the Education and Training Divisions and visits by ATC associates are sponsored by the home divisions. BCS Division, Boeing Aerospace and Electronics Division, Boeing Military Airplane, Boeing Advanced Systems, and Boeing Helicopter all have support divisions or groups with AI capabilities.

Some AI technologies have been transferred to divisions that can best use and fund them; for example, machine vision and robotics were transferred to Boeing Aerospace. Internal research and development, consulting, and technical assistance support are functions of the Center for AI.

A Communications Manager in ATC is responsible for colloquia with universities, guest speaker visits, AI forums open to all employees, an annual symposium on AI, and monthly ATC-wide meetings. Boeing's infrastructure includes electronic mail and bulletin boards.

The Center for AI contributes to the corporate vision for the 1990s. Team members from the center serve on BCS's future standards committees. For example, BCS sponsors an Architecture Committee, with subcommittees chartered to develop standards. Team members serve on the Software Engineering, Hardware, and KBS Engineering subcommittees.

The Center for AI has more than 100 staff members and is organized into teams. A management unit comprised of the General Manager, Chief Scientist, and laboratory staff sets priorities for external requests, internal requests, and internal research and development. The AI skill base is also distributed across Boeing's operating companies.

FMC CORPORATION

FMC is an international conglomerate with manufacturing and mining facilities worldwide, agricultural equipment and chemical concerns, and defense equipment and research and development activities.

In late 1982, the Defense Systems Group was working on autonomous vehicle technologies as part of its land combat vehicle business. Because of lessons learned from the work in vision and autonomous control, the broad applicability of AI to FMC's other businesses – agriculture, industrial chemicals, and commercial equipment – received recognition and support from top management. In 1984, the CEO and the President and Chief Operations Director of FMC decided to make a major investment in AI as strategic technologies [A-11].

FMC decided to build a central group for applied AI research and development. The Artificial Intelligence Center (AIC) was funded as part of the Electronics, Engineering and Computer Sciences Laboratories in FMC's Central Engineering Laboratories in Santa Clara, California.

The AIC's objective was to be a leader in the application of AI in industry and defense. The emphasis was on immediate and repeating application needs. Further, FMC selected a subset of AI technologies as applicable to computing between then (1984) and 2000. The selected technologies were vision, knowledge-based planning and configurations systems, structured selection and data interpretation, intelligent human/machine interface, and computer-based training. Other objectives were to develop the technical "integration" skills – both cultural and electronic – to successfully transfer the technology to the divisions, and to leverage internal capabilities through affiliations with local universities (e.g., Stanford University) and companies (FMC purchased 10 percent of Teknowledge, an expert systems tool vendor).

The AIC was funded through division- and corporate-sponsored work. Research and development and capability development were budgeted; operating divisions and Government contracts paid for applications development.

Personnel were trained for internal development of the AIC and not for technology transfer to operating divisions and dissemination of the technologies. The

plan was to recruit talent for the center by offering an exceptionally attractive environment.

Divisions are responsible for life-cycle support of applications. The AIC transferred development technologies and integration skills to the divisions in the course of applications development.

By 1987, the AIC had about 40 professionals, 80 percent of whom held advanced degrees, half of which were Ph.D.s. In February 1989, the AIC was broken into subgroups: an AI Department tasked with applied research and applications development; a Software Engineering Group combining knowledge engineers and conventional software programmers; and a Signal Processing, Vision and Electronics Group, which handles vision technology needs. All were located in the Electronics, Engineering and Computer Sciences Laboratories. The AIC no longer trains new personnel; it now considers itself fully staffed.

An additional model for technology dissemination among the divisions is being implemented. FMC is distributing low-end expert systems tools throughout the divisions in an attempt to disperse the expertise broadly. The Central Engineering Laboratories conduct regular seminars for division personnel; AI topics are included. It also conducts a monthly 5-day KBS course in conjunction with the distribution of low-end tools.

Of 70 to 80 total applications to date, an estimated 25 have been fielded (including defense demonstration application prototypes built under contract).

Evaluation of payback is informal. Historically, no postproject audits were performed; hence, no corporate-wide figures are available. Projects have succeeded in capturing vanishing expertise from retiring personnel, and anecdotal stories tell of increased performance and financial returns.

E. I. DU PONT DE NEMOURS AND COMPANY

Du Pont, with annual revenues of more than $29 billion, is a major American company in both the chemical and oil industries. As a modern conglomerate, it has grown from its 1802 origin to produce agricultural chemicals, consumer products, biomedicine, transportation products, and plastics. The consumer experiences

Du Pont's products daily – Teflon, nylon, freon gas, Tyvek envelopes, and Philips optical disks to name a few.

Du Pont's entry into AI technologies was an outcome of its corporate planning office's function of investigating new technologies. In 1985, Dr. Edward Mahler was a liaison to emerging technologies in the Planning Department. After evaluating the technology and available commercial expert systems shells, he concluded that the ante was too high – the cost of acquiring custom expert systems tools for implementing custom solutions would be too great. To finish his evaluation, Dr. Mahler selected a few problems and built a few simple prototype systems with simple tools. That's when he struck upon a simpler, less-expensive approach.

Dr. Mahler reasoned that Du Pont had thousands of personal computer (PC)-literate users and nearly as many PCs. Even though the company had several thousand programmers, probably only a handful could program in any of the expert systems languages – LISP, PROLOG, OPS, and the like. Furthermore, Du Pont's distribution over more than 120 sites worldwide did not lend itself to cultivating a whole new way of programming. Therefore, the solution had to be simple enough to be implemented by the using expert, had to run on existing hardware, and had to address a user's real need. The plan became to provide a small (able to run on existing PCs), simple (usable by nonprogrammers), standard tool with much of the appropriate features built-in, and help the user develop and maintain his or her own application.

Du Pont's executive committee agreed to fund an AI Office to catalyze the implementation of AI, particularly KBS broadly and effectively "throughout Du Pont" [A-12]. Du Pont's corporate culture recognizes the fact that the company has operations at more than a hundred sites around the world. Management tries to foster informal and formal networks as a means for communicating ideas and solutions. Because operations are spread throughout the world, the best way a corporate group can help is to support the operating groups by serving as enablers. Rather than "pushing" the technology, the AI Office tries to create awareness, motivation, and functional capability in expert systems [A-13].

The Du Pont AI Office has 12 staff members. Its training tasks are to provide awareness courses for management, skill-building courses for potential developers (the technical domain experts), and instruction on the use of simple PC-based shells.

The AI Office staff operates a telephone hot-line and also participates in "jump starts" – joint rapid prototyping sessions of short duration. It sponsored the creation of an in-house expert systems shell – Tool Kit – because existing commercial shells were deemed too difficult for nonprogrammers to use. Tool Kit requires no programming knowledge, has built-in graphics and statistics, and is easy enough to use to be taught in a 2-day course. The AI Office staff also teaches PC MS-DOS tools obtained under site license – Insight 2+ and 1st-CLASS [A-3]. Thus, the staff provides standard tools and operating units use them to implement custom solutions. The site license lowers the operating unit's tool cost.

Du Pont's AI Office also has a technologies assessment function. The group recognizes that different expert systems tools are needed for solving different classes of problems, and potentially big problems might require complex solutions. To this end, the AI Office supports a few higher level tools and languages.

Du Pont has more than 200 systems in routine use and 600 under development or in field test [A-3].

The average payback is estimated at between 7:1 [A-3] and 15:1 [A-13]. The investments are small and the returns on investment (ROI) are comparable to those experienced by other companies applying the technologies. Du Pont also counts other forms of payback. Du Pont refers to one type of application as "principal consultant apprentice" expert systems. The principal consultant apprentice expert system handles 80 percent of the end-user problems, freeing the expert to work on the remaining 20 percent. Also, through replication of expertise, Du Pont has measured improved quality from nonexperts. Another benefit is consistency of decision making. Finally, Du Pont recognizes expert systems as a means for documenting technology and preserving corporate expertise [A-3].

LOCKHEED CORPORATION

Lockheed Corporation has five major groups: Missiles and Space Systems Group (including Lockheed Missiles and Space Company, Inc.; Lockheed Engineering and Management Services Company, Inc.; and Lockheed Space Operation Company); Aeronautical Systems Group (including Lockheed California Company, Lockheed Georgia Company, and Lockheed Aircraft Service Company); Marine Systems Group (including Lockheed Shipbuilding); Electronics Group (including Sanders Associates, Inc.; and Lockheed Electronics Company, Inc.); and Information Systems Group

(including Cadam, Inc.; Dialog Information Services, Inc.; Datacom Systems Corporation; Lockheed Air Terminal, Inc.; Metier Management Systems; and Cal Comp Products). Lockheed's Artificial Intelligence Center (AIC) is in the Research and Development Division of Lockheed Missiles and Space Company, Inc.

In late 1985, a Lockheed corporate AI task force determined a need and made the recommendation for an AIC. Within 6 months, a manager had been assigned in the Research and Development Division. The first task of the AIC was to survey Lockheed's organizations and make a situational assessment. From this assessment came the AIC's charter.

The AIC's charter has three major areas: research and technology development, technology transfer, and education and training. The AIC is organized into nine sections. The seven sections working on research and technology development are: the Validation of Knowledge Bases Section, the Human Machine Interface Section, the Real Time Symbolic Systems Section, the Advanced Reasoning Systems Section, the Generic Expert Systems Section, the Image Understanding Section, and the Autonomous Planning Section. The two remaining sections are the Technology Transfer Section and the Training and Education Section.

In addition to research in the particular areas, the sections develop, test, verify, and support AI tools, some in-house and some commercial. The AIC supports university research projects and has connections with Stanford University. The AIC also has affiliations with commercial organizations (e.g., Inference Corp. and SRI International) to help leverage AI technologies. In addition, the sections conduct externally funded research.

The Technology Transfer Section is tasked with establishing technology transfer interfaces with Lockheed's product divisions. It conducts the AIC's technical consulting with product divisions, acts as the conduit to integrate the AIC's AI research into the product divisions, and maintains the corporate AI applications database.

The Training and Education Section conducts short courses of 1 to 2 weeks in implementation skills and holds 1-day to 1-week courses for executives; those courses include an overview of AI technologies and AI project management techniques. The Training and Education Section also has a 6-month residency program. In that program, a product division nominates a candidate, approves a project, and submits a

proposal to the AIC. The resident attends 12 weeks of classroom and laboratory course work and then is assigned an AIC mentor. For the next 12 weeks, the resident and the mentor team work on the application. The resident, now a graduate from the AIC's residency program, returns to the product division with a completed project.

REFERENCES

[A- 1] Barker, Virginia E. and Dennis E. O'Connor. "Expert Systems for Configuration at Digital: XCON and Beyond." *Communications of the ACM*, Vol *32*, No. 3 (Mar 1989).

[A- 2] Telephone conversation with Jack Rahaim, Corporate Artificial Intelligence Marketing Manager, and Themis Papageorge, Manager, Strategic Planning and Third Party Programs, Digital Equipment Corporation. 1989.

[A- 3] Feigenbaum, P. E., McCorduck, and H.P. Nii. *The Rise of the Expert Company.* Times Books, 1988.

[A- 4] McDermott, John. *"R1: The Formative Years,"* AI Magazine, Summer 1981.

[A- 5] "Digital Equipment Corp. Saves Millions with Expert Systems!" *Expert Systems Strategies*, *3*: *8*. Harmon, Paul, ed. Cutter Information Corp. 1987.

[A- 6] Lynch, Frank, Charles Marshall, Dennis O'Connor, and Mike Kiskiel, II. "AI in Manufacturing at Digital." *The AI Magazine*, Winter 1986.

[A- 7] Telephone conversation with Bruce Martin, Program Manager for Expert Systems, Artificial Intelligence Project Office, International Business Machines Corp., Jun 1989.

[A- 8] Telephone conversation with Candice Matteucci, Staff Systems Analyst, Artificial Intelligence Support Center, International Business Machines Corporation. Jun 1989.

[A- 9] The Boeing Company Annual Report, 1988, pp. 4 – 22.

[A-10] Telephone conversation with Steve Yanagimachi, Project Manager, Center for Artificial Intelligence, Boeing Corp., Jun 1989.

[A-11] Telephone conversation with Perry Thorndyke, Strategic Applications Program Manager, FMC Corp., Jun 1989.

[A-12] Williamson, Mickey. "At Du Pont, Expert Systems Are Key to AI Implementation," *PC Week*, 13 Jan 1987.

[A-13] Telephone conversation with Edward Mahler, AI Program Manager, DuPont Co., Jun 1989.

APPENDIX B

DoD ARTIFICIAL INTELLIGENCE TRAINING

In order to establish artificial intelligence (AI) as an effective logistics tool able to attack and solve new and difficult management problems, AI must be widely understood as a maturing technology that is ready for use today. To establish that recognition, personnel at decision-making levels must become aware of its capabilities. Training programs must be developed for personnel responsible for daily operations and also for all levels of management personnel.

The significant policy issues include whether a specialized AI logistics training program should be established and, if so, what it should look like and who should manage it.

THE REQUIREMENT FOR A SPECIALIZED AI TRAINING PROGRAM FOR LOGISTICS

If we examine the history of conventional automatic data processing (ADP) training, we can draw parallels to AI training and develop a more comprehensive and robust DoD AI training program. Traditionally, ADP training programs have concentrated on the technical aspects of designing and implementing effective software systems. Most ADP training programs have not tried to impart any knowledge of the domain areas for which the software systems were intended. For example, very few software designers have been trained in the functions and operations necessary for a successful logistics program. Conversely, logistics training has traditionally ignored the complexities of designing and implementing the software systems necessary for effective logistics support. These training flaws have led to a weakness in the logistician's ability to convey system requirements to ADP developers and to a similar weakness in the ADP developer's ability to understand the intricacies and subtlety involved in managing and implementing an effective logistics program. This difficulty in communication between ADP developers and logisticians manifests itself in poor data system design, unnecessary schedule slippages, and cost overruns caused by frequent changes in requirement specifications.

If we follow the same training approach with AI, we can expect to see even greater problems. The complexity of the task the software must perform makes developing requirements specifications for conventional ADP software difficult even when the communication between the logistician and the system is good. The tasks AI systems are required to perform are generally an order of magnitude more complex than the tasks performed by conventional ADP software.

If DoD tries to implement AI systems on a large scale using the traditional ADP approach to training, it will compound an already complex problem by interjecting a communication barrier between logisticians and AI software developers. The solution to this problem is to ensure logisticians at all levels understand the complexities of AI software design and implementation and that AI software developers have an understanding of the logistics process.

Since AI will be used at all levels of decision making, the personnel responsible for making decisions at strategic, tactical, and organizational levels must be trained to understand what problems are appropriate for AI solutions, the capabilities and limitations of AI technology, and what is involved in the process of designing and implementing AI software. All logisticians certainly do not need to know how to perform knowledge engineering or how to design and implement AI software; rather, all should understand the basics of the process. A major component of expert system software development that every logistician should understand is knowledge acquisition. Knowledge acquisition deals with obtaining and understanding domain-specific problem solution techniques. Learning knowledge-acquisition techniques teaches logisticians how to logically analyze logistics problems and enables them to prepare more effective specifications for automated solutions to their problems.

Expert systems is the AI technology most intimately connected with the domain in which it is applied. Therefore, it is most important that domain practitioners have a good understanding of what is involved in developing expert systems and what the capabilities and limitations of those systems are. Other fields of AI are not as closely tied to specific domain knowledge as expert systems; therefore, logisticians do not have to be as familiar with the technologies involved. However, it is still important that logisticians understand the capabilities and limitations of each of the AI technologies. Understanding the capabilities and limitations of AI technologies such as vision, speech, and intelligent robotics is difficult since those technologies change rapidly, in some cases almost monthly. An introductory course to AI can convey the

capabilities and limitations of AI technologies to logisticians, and within a very short time, the information might be outdated. For example, when DoD Components began AI training in 1986, natural language technology was only cost-effective for applications involving very large systems. At that time, effective natural language systems cost \$90,000 – \$100,000. However, by mid-1987, very powerful natural language systems were commercially available for less than \$700. Managers, especially those who will make decisions about applying AI technology, need to understand that the information provided in AI training is changing constantly, and that systems that may not have been feasible at the time of their training may be excellent applications 6 months later. Managers should attend annual refresher courses in AI technology or take other active measures to stay abreast of the technology.

To summarize, the history of ADP training has shown that logisticians should understand what is involved in the development of their automated systems, including AI. Furthermore, understanding the knowledge-acquisition process can provide logisticians valuable insight into their decision-making processes. Finally, logisticians should understand the capabilities and limitations of other AI technologies so that they know what AI technology can and cannot do for them.

A SAMPLE DoD AI TRAINING PROGRAM

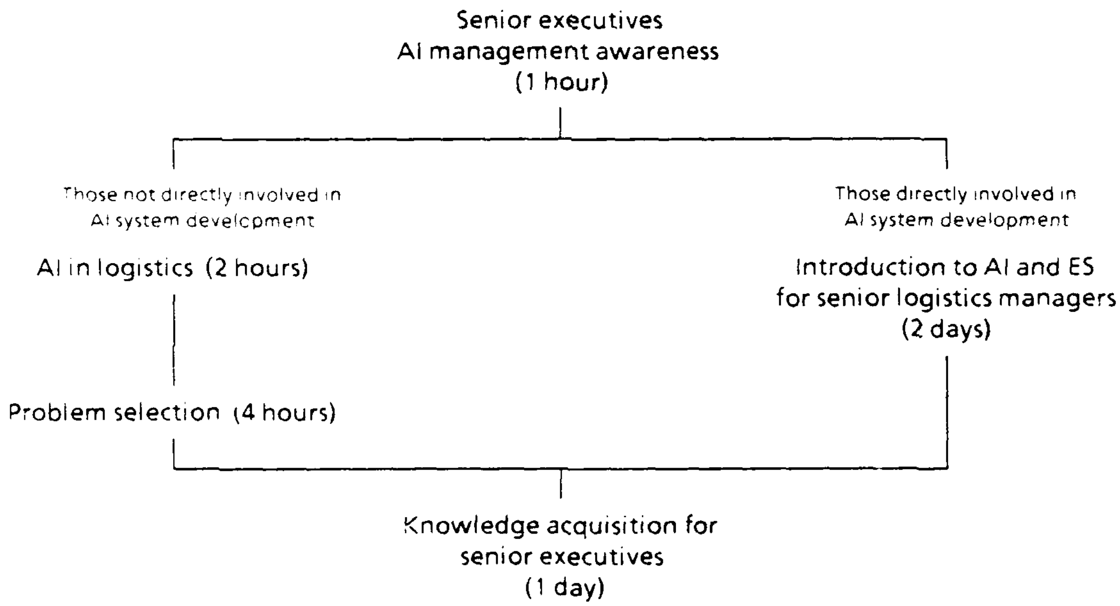
Any training program structure for an organization as large as DoD must recognize that differing levels of knowledge are needed. The need for knowledge about AI varies not only with the position of an individual in DoD, but also with the likelihood that the individual will be directly involved in an AI development effort. While it might be useful to educate, in depth, all logistics personnel at all levels in AI and expert systems, that approach is not feasible. More rational objectives are to make everyone aware of the technology and to give the in-depth knowledge to those people most likely to employ AI in their jobs.

The training program outlined in this appendix recognizes the varying need for knowledge by different people throughout DoD. The senior level courses are intentionally brief, since most senior executives have little time for training and need to acquire as much knowledge in as little time as possible. The training program also recognizes a difference in the need for knowledge between those who are not likely to be involved in the near future in AI development and those who will. Sample course

sequences discussed herein and the sample course outlines presented are intended to show the type and extent of knowledge needed by different logisticians within DoD. The *DoD AI Policy Office (AIPO) should determine* the specific training targets, courses, and durations.

Senior Level Executives

A program similar to Air Force System Commands' Project Bold Stroke for Air Force software should be established for DoD logistics AI. The program would educate general officers and other senior executives on the capabilities and limitations of AI technologies as well as what AI means to logistics. The more senior decision makers know about AI the better they will be able to make decisions about its use in their Services. Senior officers also need to be educated on the strategic implications of AI. AI can be applied to strategic and national policy planning as well as to the execution of tactical policies. A proposed AI training program for general officers and senior executives is shown in Figure B-1. (Sample course outlines for all proposed courses are presented at the end of this appendix.)



Note: ES = Expert System.

FIG. B-1. PROPOSED AI TRAINING PROGRAM FOR SENIOR EXECUTIVES

Middle Management/First Level Supervisors

Middle management and first level supervisory personnel need a more thorough understanding of the application of AI to their daily operations. These managers will ultimately be required to commit limited resources to AI development efforts. Even if the bulk of the AI development is contracted out, the first levels of management will still be required to commit their task experts to the development projects since it will be their experts' knowledge that the developers will capture and place in an automated system. Therefore, it is essential that personnel at this level understand the advantages of using AI. The role that senior management should play here is to make subordinate management understand the importance of accepting short-term costs in some cases in order to achieve greater long-term benefits. As a minimum, all personnel at this level should attend a problem identification course and a knowledge acquisition course. This area could see tremendous benefits from training personnel in the knowledge acquisition process. Conventional ADP has not been able to deal effectively in the past with the problems of middle and upper level management. Knowledge acquisition will enable management to analyze their tasks and develop expert system requirements to better solve these problems. Figure B-2 shows the proposed training program for middle managers and first-level supervisors.

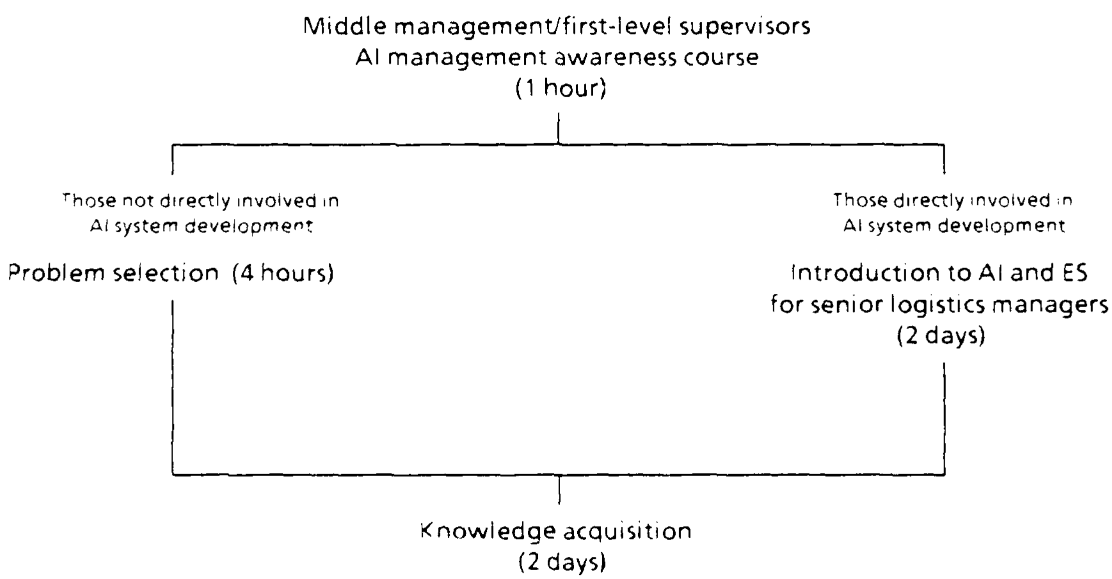


FIG. B-2. PROPOSED TRAINING FOR MIDDLE MANAGEMENT

Line Personnel

Line personnel will ultimately either use or implement DoD's AI systems or will deal with contractors who will implement them. Personnel in all functional areas need to understand what makes a task a good candidate for an AI application and how to properly scope and define the application. Many personnel at this level will need to understand how to go beyond simple problem identification; that is, they will need to know how to develop and implement actual AI applications. As a minimum, these personnel should attend a course in problem selection and knowledge acquisition. Personnel desiring to develop AI applications should also attend additional courses in the expert system (ES) development process and AI development tool programming. Figure B-3 shows the proposed training program for line personnel.

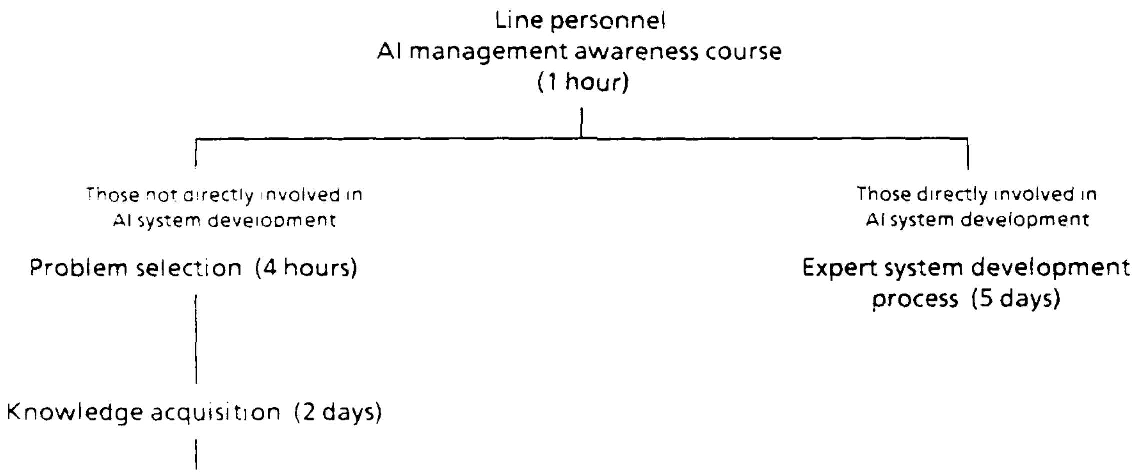


FIG. B-3. PROPOSED TRAINING PROGRAM FOR LINE PERSONNEL

MANAGEMENT OF THE AI TRAINING PROGRAM

DoD has three basic options on who should manage AI training.

Option 1: Each Service Could Manage Its Own Program

The Services have already established their training programs and have met with reasonable success to date. In addition, some of the resources required by this option are already in place. However, this option represents a decentralized approach that tends to diffuse the available AI training talent, which is currently at a

premium. Training expertise would be dispersed across the Services and a greater expenditure of personnel resources dedicated to training would be required. Hence these individuals would not be available to implement and manage AI systems.

Option 2: OSD Could Designate a Single Service To Manage the Program for DoD

This option has the advantage of concentrating AI training resources within one location and thus making better use of a scarce resource. It also has precedents within the DoD software community. For example, the Marines run the DoD OS 360 Systems Programming Course for all Services. This option is in accord with the OSD preference for centralizing the procurement of AI hardware, software, and services within one activity. Again, some of the resources to accomplish this option are already in place. It makes sense to centralize the AI training to use the hardware and software purchased through the central procurement source. The drawback to this option is that the DoD Components not selected to manage the training program may be reluctant to participate.

Option 3: OSD Could Manage the Program Centrally Through the DoD-Wide Technology Transition Center

This option is advantageous in that AI training resources would be concentrated within one location. It would offer the same benefits that hold for Option 2.

We recommend that OSD pursue Option 3 at this time. This option will be more readily accepted by the DoD Components since it will guarantee all equal access to AI training. Central management of training funds by DoD will also ensure minimal duplication of effort when contracting for training services.

A primary function of the DoD-wide Technology Transition Center (TTC) should be to evaluate AI curricula in DoD and academia to determine their suitability for use within DoD. After assessing the suitability of existing curricula, the DoD TTC should identify shortfalls in the existing curricula and establish guidelines for further incorporation of AI into logistics curricula development to correct the existing shortfalls. An additional function of the DoD TTC should be to establish minimal requirements for certified logistics AI instructors, and those requirements should be used by the DoD Components. After the DoD TTC has established the necessary curricula and minimal requirements for logistics AI

instructors, these guidelines could be provided to "mini-TTCs" within the DoD Components. These "mini-TTCs" would conduct the logistics AI training. Establishment of the mini-TTCs does not preclude contracting for either the study of necessary AI curricula or the execution of the logistics AI training. The decision to contract training services or to perform the work organically should be at the discretion of the individual DoD Component. The remainder of this appendix presents sample AI training course outlines.

SAMPLE DoD AI TRAINING COURSE OUTLINES

Management Awareness of AI
(1-hour course)

I. Introduction/Overview

II. Artificial Intelligence Technologies

   A. Expert systems

   B. Natural language

   C. Speech

   D. Vision

   E. Intelligent robotics

   F. Neural networks

III. State of the Art in Applied AI

   A. Capabilities/success stories

   B. Limitations/failures

IV. Applications in Logistics

AI in Logistics
(2-hour course)

I. Introduction/Overview

II. Basics of AI & Expert Systems for Managers

III. Benefits and Risks

IV. Logistics Applications of AI

  A. Transportation

  B. Inventory management

  C. Maintenance

  D. Warehouse management

  E. Integrated logistics support

  F. Acquisition

V. Strategies for Implementing AI Programs

VI. Other Advanced Technologies and Logistics

Expert Systems Problem Selection
(4-hour course)

I. Introduction/Overview

II. Applying Expert Systems

III. Limitations of Expert Systems

IV. Problem Selection Criteria

   A. Is an expert system possible?

   B. Is an expert system justified?

   C. Is an expert system appropriate?

V. Problem Selection Exercises and Case Studies

Introduction to AI and Expert Systems for Senior Logistics Managers
(2-day course)

I. Introduction/Overview

II. AI Technologies

   A. Expert systems

   B. Natural language

   C. Speech recognition

   D. Vision

   E. Intelligent robotics

   F. Neural networks

III. Applying Expert Systems

IV. Limitations of Expert Systems

V. Problem Selection Criteria

   A. Is an expert system possible?

   B. Is an expert system justified?

   C. Is an expert system appropriate?

VI. Case Studies

VII. Development Resources Required

VIII. Expert System Life Cycle

IX. Testing Expert Systems

Expert System Development Process
(5-day course)

I. Knowledge-Based System Life Cycle

A. Requirements analysis

1. Knowledge to be acquired during the initial phase
2. Type and scope of the problem
3. Expertise needed
4. Time needed to develop the system
5. Resources
6. Goals
7. Estimating return on investment

B. Preliminary design

1. Knowledge to be acquired during later phases
2. Gathering concepts, relations, and control mechanisms
3. Identifying subtasks, strategies, and constraints
4. Level of detail needed for the knowledge base

C. Detailed design

1. Selecting a tool/shell
2. Developing a knowledge-base structure and representations
3. Planning the delivery environment and user interface

D. Code and unit test

1. Coding the knowledge base
2. Testing the knowledge base

E. System/integration testing

1. Verification and validation
2. Performance testing (dynamic testing)
   (a) Evaluating the performance of knowledge-based system
   (b) Evaluating the accuracy

3. Structural testing (static testing)
   (a) Consistency
   (b) Completeness

F. Maintenance
   1. Correcting deficiencies
   2. Improving performance
   3. Improving accuracy
   4. Enhancing usability
   5. Microcosm of development process

II. Resources
   A. Team structure
   B. Schedule
   C. Documentation
      1. Types of documentation
      2. Levels of documentation
   D. Cases
      1. Kinds of cases
      2. Number of cases
      3. Case management facilities

III. Interviewing Techniques
   A. Methodologies
   B. Dealing with difficult experts
   C. Combining knowledge from multiple experts

Knowledge Acquisition for Senior Executives
(1-day course)

I. Introduction

II. Requirements Analysis

  A. Knowledge to be acquired during initial phase

  B. Type and scope of the problem

  C. Expertise needed

  D. Time needed to develop the system

  E. Resources

  F. Goals

  G. Estimating return on investment

III. Preliminary Design

  A. Knowledge to be acquired during later phases

  B. Gathering concepts, relations, and control mechanisms

  C. Identifying subtasks, strategies, and constraints

  D. Level of detail needed for the knowledge base

IV. Interviewing Techniques

  A. Methodologies

  B. Dealing with difficult experts

  C. Combining knowledge from multiple experts

Knowledge Acquisition
(2-day course)

I. Introduction

II. Requirements Analysis

   A. Knowledge to be acquired during initial phase

   B. Type and scope of the problem

   C. Expertise needed

   D. Time needed to develop the system

   E. Resources

   F. Goals

   G. Estimating return on investment

III. Preliminary Design

   A. Knowledge to be acquired during later phases

   B. Gathering concepts, relations, and control mechanisms

   C. Identifying subtasks, strategies, and constraints

   D. Level of detail needed for the knowledge base

IV. Detailed Design

   A. Selecting a tool/shell

   B. Developing a knowledge-based structure and representations

   C. Planning the delivery environment and user interface

V. Interviewing Techniques

   A. Methodologies

   B. Dealing with difficult experts

   C. Combining knowledge from multiple experts

VI. Knowledge Acquisition Exercises

APPENDIX C

KEY TARGET APPLICATIONS OF ARTIFICIAL INTELLIGENCE TO LOGISTICS

The key logistics applications of artificial intelligence (AI) are presented here in terms of near-term and long-term initiatives. Near-term initiatives are those that rely on existing, mature technology and can be implemented without further research and development. Long-term initiatives involve relatively mature laboratory technologies, but they are technologies that have not yet been applied in a real-world environment and may, therefore, require additional research and development.

This list of key target applications is not intended to be all inclusive. In fact, one of the early tasks of the OSD Logistics and AI Policy Council should be to determine the specific target applications for DoD and the emphasis to be given to each. One of the key findings in the review of corporate involvement with AI was the necessity to examine AI from the perspective of the essential business needs of the organization. Table C-1 provides a framework OSD can use in comparing the AI technologies with the organizational needs. Obviously, the list of organizational needs included in Table C-1 is only a beginning of the actual list of OSD's needs.

The number of potential high-leverage applications in DoD logistics is enormous. The productivity and quality gains to be realized from these potential applications are so significant that DoD should place special emphasis on the development of software to meet the needs of key DoD Components responsible for these functions.

NEAR-TERM APPLICATIONS (1 TO 3 YEARS)

Off-Equipment Maintenance

We recommend that OSD establish a DoD-wide policy on AI-based maintenance systems for newly acquired weapon systems and nonweapon capital equipment. Given the current state of technology, every weapon system procured by the Services should be delivered with intelligent maintenance aids. As part of the weapon

TABLE C-1

TECHNOLOGY NEED ASSESSMENT

Organizational need	Expert systems	Natural language	Speech	Vision	Neural networks	Intelligent robotics
Data verification						
Training						
Diagnostic aids						
Enhanced access to information						
Real-time data capture						

system's support equipment, defense contractors should be required to deliver knowledge-based systems (KBS) capable of diagnosing and isolating faults to a level sufficient for both organizational and depot-level maintenance functions. The organizational-level KBS could easily be required to fit inside a computer system no larger than a lap-top computer and in some cases, a hand-held computer. The depot-level KBS must be integrated into the designated automatic test equipment. Diagnostic applications such as these will reduce the number of personnel required to maintain systems, reduce the number of Cannot Duplicates and Retest Okays, reduce the time required to isolate and repair components, and reduce the number of spares needed to support the weapon systems.

Transport Loading (Ship, Plane, and Truck)

A major problem confronting military logisticians today is how to efficiently load cargo transports so that the vital material is accessible and unloading time is minimized. Efficient loading is especially critical in combat situations in which certain materials must be unloaded as rapidly as possible. In setting up forward bases, some materials may need to be unloaded and set up before other materials can be unloaded. When the complexities of proper weight and balance are taken into account for aircraft and ships, the problem of properly loading a transport becomes even more complex. Both the Air Force and the Navy are making some early attempts to develop this kind of KBS, but their efforts need to be expanded so that all military airports and shipping terminals have access to the technology.

Route Planning

In periods of hostility, rapid and accurate route planning may be crucial to the success of logistics operations. Systems need to be developed that consider route time, distance, terrain and meteorological conditions, and potential military threats in the area. Many route-planning systems are being developed for commercial applications and even a few for military logistics. However, few if any consider factors other than time and distance. While minimizing time and distance is certainly important, military logisticians must also take into account intervening terrain, meteorological conditions, fuel availability, equipment capabilities, threats from the enemy, and time-critical situations. These tools could also serve as valuable training aids and allow war planners to simulate various wartime scenarios.

Data Validation

While data validation may not seem as important as applications such as fault diagnosis and route planning, its value is obvious from the tremendous amount of press generated when someone sells DoD $400 hammers. Data validation systems can play important roles as intelligent front ends to DoD's purchasing and requirements databases. These systems in effect extend the editing capabilities of the existing conventional data systems. Today's data systems perform exceedingly well at detecting and preventing incorrect types of data from being entered by humans. Errors such as entering "$1w3.00" instead of "$123.00" are detected. Conventional data systems are not capable of detecting errors where the data type is correct but the value is inaccurate, errors such as "$132.00" when "$123.00" was

intended. Such errors are also the most frequent type of data entry error. They arise out of misplaced decimal points, transposed digits, or simply hitting the wrong key on the input data terminal. Simple data range tests are frequently incapable of handling such subtle errors. KBS technology allows system designers to develop the capability of detecting inaccurate data values by applying human-like reasoning to the data entry process. These applications can save millions of dollars.

Spares Determination

Many conventional modeling techniques have been developed to determine when and where spares will be needed in the event of hostilities. However, these models take a fairly static view of the world and can be difficult to use. Several hours of work may be required to determine what parameters need to be entered into the system to obtain a reasonable response. Further, these models generally assume fairly constant attrition rates of men and material and make no allowances for cannibalization of equipment. These limitations are primarily due to the combinatorics of the situation; if these systems considered all possible variables, they would take far longer to run and would have only limited utility. Intelligent simulation, i.e., KBS combined with conventional modeling techniques, can make these systems easier to use and much more flexible, while increasing the responsiveness of the models.

Acquisition Support

Writing and assembling procurement packages has become a tedious and complex problem. Still, the majority of DoD's contracting expertise resides in-house. KBS offer the opportunity to capture DoD procurement expertise and assemble it in a system capable of preparing complete procurement packages.

Several small systems attempt to solve one small part of this very large problem. The Software Support Decision Aid identifies the correct DoD-STD-2167A data item descriptions (DIDs) to be placed on contract to procure software documentation. The Expert Tailoring Assistant Design for Testability develops statement of work (SOW) tasks for including system testability in system design. Systems need to be developed for all aspects of weapon system procurement and then integrated into a single acquisition support system.

Indeed, the major finding of a 1988 study on the current status of automated SOW systems by DoD organizations was that "SOW automation system development in DoD is proceeding in a fragmented, uncoordinated fashion. Some degree of coordination and control appears desirable." [C-1] Another suggestion of the study was that Computer-Aided Acquisition Logistic Support (CALS) requirements be built into the system. The requirement that a contractor provide a knowledge-based diagnostic aid with the prime weapon system could also be a built-in requirement. Another feature recommended for automated systems is a schedule consistency checker.

> While this was not a point of concentration in this study, inconsistencies between related data elements is a very common problem in practice. The engineering drawing, Reliability and Maintainability (R&M), Logistics Support Analysis Record (LSAR), and Integrated Logistics Support (ILS) element Data Item Descriptions (DIDs) are an outstanding example. The problem occurs because DoD schedules backwards, i.e., based on data needs to meet deployment and other higher level schedule needs, without regard to when the data can be logically available. A schedule consistency check can be built into a Contract Data Requirements List (CDRL)/Data Element Selection automated system at reasonable cost.

The advantages of a set of KBS for acquisition support could be tremendous, especially if implemented DoD-wide. Federal acquisition regulations permit a great deal of technical variation around a core of basic requirements. A benefit of acquisition-oriented systems would be their ability to facilitate consistent performance in developing boilerplates and the completion of frequent, repetitive procurements of noncomplex items or services. Contracts would be more complete since the KBS would ensure important aspects of the contract were not overlooked. Finally, the KBS could keep an audit trail of the decisions made in the development of the procurement package.

Integrated Logistics Support

Integrated Logistics Support consists of many interrelated and independent logistics areas that must be examined in great detail when developing and supporting weapon systems. Very seldom do acquisition and support organizations have personnel knowledgeable in all areas of ILS. Yet the organizations must develop requirements and documents such as the Integrated Logistics Support Plan (ILSP), the Computer Resources Life Cycle Management Plan (CRLCMP), and others. KBS now allow DoD to capture expertise in each of the ILS elements and provide that expertise in electronic form to acquisition and support organizations.

That ability will be of great value to OSD in the near term. For example, a near-term system might guide a logistician through the review process for a specific element of ILS, such as the manning required to support a new weapon system.

Nondestructive Inspection

Intelligent Nondestructive Inspection (NDI) systems with the capability to automatically analyze component X-rays, spectrograms, eddy current patterns, and fluoropenetrant dye patterns will greatly reduce the time it takes to analyze mechanical structures. Expert systems have been analyzing spectrograms for years. For example, DENDRAL was an expert system designed to decipher molecular structures based on the spectrogram of chemical compounds.

Currently, the major impediment to application of AI to NDI is the lack of an adequate vision system. However, the type of vision necessary for interpretation of images from X-ray photography and fluoropenetrant dyes is an order of magnitude simpler than that required for three-dimensional scene recognition. Hence, these systems should be available within the next 2 to 3 years. General Electric is currently working at applying neural networks to interpreting both fluoropenetrant dye and X-ray images. GE expects to have a system for fluoropenetrant dye inspection available within the next year. These systems will increase the accuracy with which defects in mechanical structures are identified. In the long term, when combined with flexible machining centers, NDI systems will automatically repair the defects. Other long-term applications are addressed in the following section.

LONG-TERM APPLICATIONS (3 TO 5 YEARS)

Equipment Decontamination

Chemical, biological, and radiological (CBR) environments are highly hazardous to humans. The combination of KBS, three-dimensional vision, and advanced robotics will soon make possible the development of intelligent robots capable of operating in the real world and performing complex, hazardous tasks. An equipment decontamination system could operate in the field to autonomously decontaminate ships, planes, tanks, and any other contaminated vehicles. These systems would eliminate the need for support personnel to enter hazardous CBR environments.

On-Equipment Maintenance

As embedded computer systems become faster and more powerful, off-equipment diagnostic systems can be embedded into weapon systems. They will provide the same benefits previously discussed with the added benefit of increased mobility and reduced support equipment.

Damage Assessment

Ships, planes, ground vehicles, and facilities are subject to severe battle damage that may render their on-board diagnostic systems inoperative. Battle damage assessment systems will provide the capability to identify damaged components and recommend repair actions to maintenance personnel based on external visual inspection of the vehicle or facility. Eventually, these systems may be able to make the repairs themselves.

Automated Repair Systems

In the longer term, many of the diagnostic systems developed in the next 1 to 3 years will be expanded to automated repair systems. They will accept failed electronic components, determine the source or sources of failures, and execute the repair procedures. These systems will be able to deal with multiple failures within single components.

Flexible Machining Centers

Flexible machining centers will combine intelligent NDI with computer-controlled manufacturing and repair techniques to automatically produce good mechanical parts. These systems will operate much like the automated repair systems. Flexible machining centers will accept failed components such as jet engine disks or tank armor, apply the appropriate NDI procedure to detect the structural flaws, and determine the most appropriate repair process. The system will then carry out the repair process, apply the necessary quality checks, and produce a repaired component.

RESEARCH WILL BE REQUIRED

The applications cited herein should be followed up with research. However, the first step in this process is for OSD to determine its specific needs and then match those needs against existing technical capabilities for each AI technology area. With

that analytic approach, OSD can determine the major areas in which research is required to support the logistics AI initiatives. Research will be required in several areas and should be supported and funded. Major policy issues to be resolved by the OSD Logistics and AI Policy Council concern (1) how these research initiatives will be funded and (2) the process for identifying the research requirements and setting their priorities.

REFERENCES

[C-1] Telephone conversation with Dick Biedenvender, ERC International. May 1989.

APPENDIX D

DETERMINING WHEN TO INVEST IN ARTIFICIAL INTELLIGENCE

This appendix provides criteria and other relevant information for the selection and justification of artificial intelligence (AI) projects. It offers useful guidelines for the Military Services in making their selections.

SCREENING ARTIFICIAL INTELLIGENCE PROJECTS

Since the criteria for judging the value of nominated AI projects vary to some extent with the technology being considered, we have divided this section along AI technology lines. We discuss in order the criteria for judging the value of expert/knowledge-based systems (KBS) applications, natural language systems, speech recognition/understanding systems, three-dimensional vision systems, intelligent robotic systems, and neural networks.

Three major factors must be considered when evaluating AI projects: the feasibility, appropriateness, and economic justification for the project. First, one must determine whether an AI solution is feasible, i.e., whether the success of the project in achieving its goals through the application of AI technology is reasonably probable. The second factor is the appropriateness of applying an AI solution, i.e., whether the use of AI techniques is the best solution or whether more conventional techniques would serve as well. The final factor that must be considered is the economic justification or payback. Will the solution be justified? What is the value added to the mission effectiveness of the using organization?

In the following sections, we discuss the criteria for judging the feasibility, appropriateness, and justification of developing an AI application. We examine a payback model and the merits of standardized payback models. Finally, we propose criteria to establish priorities for nominated AI projects.

Expert/Knowledge-Based Systems

An expert/KBS requires several features. First, at least one human expert or comparable source of knowledge must be available so that the system developer

(knowledge engineer) can extract knowledge about the task to be performed. Further, management must be willing to commit a substantial amount of the expert's time to the development project.

The expert must be capable of communicating knowledge about the task to the knowledge engineer with enthusiasm. The task must require that the expert exercise some judgmental knowledge. The expert does not have to be physically present to perform the task; the system developer and the expert should be able to communicate telephonically, and the system developer should be able to perform the task by simply receiving verbal instructions from the expert.

The task should not require the use of common sense. Common sense is the knowledge that most humans draw on to be able to function in the real world. The knowledge is extremely diverse and requires access to a vast storehouse of information. Encoding of common sense knowledge is still beyond the capabilities of AI systems.

A task is appropriate when certain characteristics indicate that the best approach is an expert/KBS and when more conventional solutions are not sufficient. The task should be defined clearly and should require the use of heuristics or rules-of-thumb. It may require that a solution be derived in the absence of complete or certain knowledge. At the start of the project, the knowledge engineer, the expert, and the users must have a clear understanding of exactly what the KBS will do.

Given today's level of technological development, the task should be one that can be performed by the human expert in 1/2 to 8 hours. If the task can be performed too quickly by the expert (i.e., in less than half an hour) then it is probably one that is too simple to warrant developing an expert/KBS. On the other hand, if the task takes the expert more than 8 hours to perform, it is probably too complex to be developed within a reasonable amount of time.

The task should be sufficiently narrow. The expert/KBS should not deal with a wide range of topics; it should be confined to one specific task. If the task is not narrowly defined, the KBS will tend to become too large to be manageable and the development team will have a greater tendency to stray from the original purpose of the development effort.

If a conventional computer program can perform the task with an acceptable degree of precision within an acceptable period of time, the most appropriate solution is probably the conventional computer program. Such a choice does not mean that a KBS could not perform the task as well as the conventional solution; it means that conventional solutions are generally more readily accepted because they do not require special expertise to maintain or support and easily fit with other conventional systems.

Performance of the task should require the manipulation of symbolic information, or information that is represented by such words as large, small, blue, or green. Symbolic information has no intrinsic meaning or value in itself; its only meaning or value is what we infer. It may, at times, be ambiguous. Numeric data, on the other hand, is unambiguous and is readily processed by conventional computer programs. If the task can be performed solely by manipulating numeric information, then it can probably best be performed using a conventional computer program. However, a valid application for a KBS that deals with numeric data could be the determination of the correct numbers to be used in an algorithm under different sets of circumstances. In those situations, the numeric information is part of the conclusion. The description of the situation that determines which numeric data to use is the symbolic information the system will process.

Natural Language Processing

Two factors should be considered when determining the feasibility of applying a natural language system. The first concern is the size of the vocabulary needed to perform the task. As a general rule, the vocabulary needed to perform the task should not be larger than a few hundred words. If more than a few hundred words are required, the system will not perform as rapidly and the ambiguities in the vocabulary will be difficult to resolve. The complexity of the grammar needed to convey the concepts about the tasks being performed must also be considered. Current state-of-the-art natural language systems are unable to deal with very complex sentences. Therefore, the concepts about tasks to be performed by natural language systems should be ones that can be stated in sentences composed of phrases connected by simple Boolean logic (and, or, not).

A natural language system is appropriate in situations in which individuals need to perform tasks on computers but nave neither the desire nor the time to learn

complex command languages. Natural language systems generally have their greatest utility in permitting senior management personnel to retrieve information from a database. Those individuals typically do not have the time to learn database query languages or complex command languages.

Another task characteristic that points toward a natural language system is the method required to access information. If the prospective users need to access information in an ad hoc manner, then the application is probably best addressed by a natural language system. Ad hoc information retrieval exists when information must be retrieved from a database for which any two queries and display formats are rarely alike. Managers typically make the most frequent use of ad hoc information retrieval. If the prospective users generally retrieve and display information in a relatively few standard ways, their needs are best served using a menu system. Natural language systems are also useful for analysis of message traffic. These systems can flag critical messages during periods of intense activity associated with war or emergency actions.

Speech Recognition/Understanding

The criteria for determining whether a speech recognition system is possible are similar to the criteria for a natural language system. However, a natural language system processes text, whereas a speech system processes spoken words. The vocabulary of a speech system must be fairly small, limited to a few hundred words at most. If there is a requirement that the system be able to handle multiple users, the size of the vocabulary for each user must be even further reduced. If the system is required to be independent of the speaker, the vocabulary must be limited to 20 to 30 words. Further, the word structure should be restricted to one- to-three word phrases. Current speech recognition systems are not able to deal well with continuous speech, a limitation that will probably be eliminated within the next 2 to 3 years.

The final criterion for a speech system is that the background noise must be controllable. Hence, the system must either operate in a relatively noise-free environment or must have a means (i.e., noise limiting or directional microphone) to reduce the background noise.

A speech recognition system is appropriate in any environment in which the users must either have their hands free to perform other tasks or must be able to

move about freely. Some examples of locations at which users must have their hands free to perform other tasks are vehicle or aircraft maintenance. Aircraft inspection after periodic depot maintenance is an activity in which the user of an expert maintenance system might need an integrated speech recognition system to allow the technician to communicate with the KBS while moving about the aircraft.

Three-Dimensional Vision

The current state of the art in three-dimensional vision is practical for only very simple objects. Current vision systems are effective for applications that involve recognizing regular shapes (i.e., squares, rectangles, triangles, etc.) and straight lines. If the application requires that the three-dimensional vision system be able to recognize the relative positions of objects, then the application is one best left to the future. Current three-dimensional vision systems capable of recognizing objects and relative position are extremely slow. They sometimes require the power of a supercomputer for several hours just to process one scene.

Unfortunately, given the current level of technology, no guidelines are available to indicate when a three-dimensional vision system might be appropriate. The few successful systems in use today are predominantly used in custom plate welding. Some future applications of three-dimensional vision might allow robots to visually acquire objects or might be used in aircraft/vehicle inspection/cleaning, remote sensing, target acquisition and tracking, and nondestructive inspection activities such as X-ray analysis.

Intelligent Robotics

Intelligent robotics is the least mature AI technology discussed in this study. An intelligent robot depends on many of the other AI technologies working in concert. It requires KBS to provide the decision-making capability and control, three-dimensional vision to perceive its world, and mechanical manipulators to enable it to alter objects in the real world.

To determine whether an intelligent robotic system is feasible, a KBS and a three-dimensional vision system capable of performing the reasoning and perception functions of the robot must first be possible. Next, the environment in which the system will operate must be constrained in order to minimize the number of random events occurring around the robot. This will reduce the amount of processing

required and minimize the likelihood that the robot will encounter an unprogrammed situation. One means of constraining and controlling the amount of uncertainty in the environment is to provide the robot clearly marked paths or areas within which to operate. Humans and other objects are then restricted from this area. Another means of reducing random events in the robot's world is to narrow the robot's scope of operation to a specific task in which it is unlikely any random events will occur. Limitation of the scope of operation is common on assembly lines where robots are used for visual inspection of complex parts.

An intelligent robot is appropriate in situations in which it is uneconomical or hazardous to place humans. These situations include: nuclear reactor inspection and equipment repair in a chemical, biological, or radiological (CBR) environment. An intelligent robotic system may also be appropriate in highly repetitive situations in which humans become bored or in which a high degree of precision and consistency is required. These situations include visual parts inspection and nondestructive inspection (NDI) of structures. Many repetitive quality assurance inspections that require inspection of a product and either the disposition or repair of the product may also be appropriate candidates for an intelligent robotic solution.

Neural Network

Neural networks have been in existence for more than 20 years, but only recently have they been applied to real-world problems. The current level of technology in neural networks makes them adequate for fairly small problems. Neural networks are essentially pattern recognizers that are sometimes linked to vision systems. Tasks that require the recognition of recurring patterns are generally candidates for neural networks.

Development tools based on neural networks are sometimes used to implement KBS. When that occurs, the criteria for KBS should be examined to determine whether the application is possible and appropriate. Selecting a neural-network-based tool over a more conventional rule-and-frame-based tool is primarily a matter of personal preference. The one criterion for neural networks that differs from a criterion for KBS, in general, is the latter's requirement for a human expert. Since neural networks are capable of discovering patterns in data independent of a human expert, they are not as reliant on human knowledge for development as are conventional KBS. However, the question of performance validation remains.

Without a human expert, the performance of a neural network application may be difficult to validate. For that reason, anyone attempting to build a KBS using a neural network in the absence of a human expert is strongly advised to proceed cautiously. Other than being somewhat less reliant on a human expert than conventional KBS, the advantages of current neural-network-based knowledge tools over conventional tools are nebulous at best.

The criteria for neural networks are essentially the same as for KBS. Frequently neural networks serve simply as another knowledge representation methodology, much like rules, frames and semantic networks. However, neural networks are very good at discovering and recognizing patterns in large databases.

JUSTIFYING AN ARTIFICIAL INTELLIGENCE SOLUTION

In justifying an AI solution, operational effectiveness and economic considerations must be weighed. Operational effectiveness involves retaining crucial expertise and having it available at all times, in all locations, and under all conditions. Expertise critical to a mission may be lost through the retirement of experts before new workers can develop the expertise.

In another case, the expert may be promoted to a position that requires management talent, for example, rather than technical expertise. The expertise remains with the organization but not where needed. This latter problem occurs often in DoD. To be promoted, DoD personnel in scientific and engineering disciplines must move to management positions. Thus, their technical expertise is effectively lost to the organization.

In yet a third case, a critical expertise may simply be scarce. For a variety of reasons the organization may have a difficult time recruiting personnel with certain capabilities, or the expertise may be needed in many locations or in locations at which it is impractical or impossible to place human beings.

In addition to operational effectiveness, AI solutions should be justified on the basis of economics. The cost savings produced by using the system should outweigh the cost of developing, fielding, and maintaining the AI system. The factors that must be considered when determining the return on investment (ROI) for an AI system are addressed in the next section.

EVALUATING ARTIFICIAL INTELLIGENCE PROJECTS

The Services should use a standard payback model for assessing the payback resulting from the application of AI technologies. The same standard model can be applied to all of the AI technologies discussed in this report. Use of a standard payback model has many advantages. First, it ensures organizations submitting projects consider all the salient factors when computing the costs and benefits of AI applications. In the past, organizations not using a standard payback model generally underestimated the cost of maintaining software, if they even considered software maintenance. Use of a standard model will ensure everyone estimates costs and benefits in a consistent manner. Obviously, the degree to which the life cycle cost (LCC) analysis is formalized will depend upon the size of the AI system being developed. It would not be appropriate to spend more time and money justifying an AI system than was invested in the development of the system.

The standard model should consider the total LCC of the system. The LCC of the AI system comprises the development, fielding, and maintenance costs. Each of those costs is examined in turn in the following discussion.

DEVELOPMENT COSTS

Development Hardware Costs

The development hardware costs include all the hardware necessary to develop the primary computer software (i.e., the primary computer, printers, workstations/terminals, etc.) as well as any support hardware (local area networks, modems, communication lines, etc.) necessary to develop the AI application.

Development Software Costs

The development software includes the software, such as compilers, operating system, and KBS development tools necessary to develop the application software. The development software costs also include the costs of developing the user and maintenance documentation and the documentation software (i.e., word processor, desktop publishing software, etc.)

Development Personnel Costs

The development personnel costs include the costs of the expert, knowledge engineer, software programmer, policy representative, and any additional personnel

required to develop the AI application. Those costs are generally quoted as the individual salaries plus the costs of overhead required to support the personnel.

Time to Complete Development

The time to complete development is the amount of time, generally in years and fractions of years, from inception of the development effort until the system is declared ready for operational use.

Total Development Costs

$$\textit{Total development costs} = \textit{hardware costs} + \textit{software costs} + (\textit{personnel costs} \times \textit{development time}).$$

FIELDING COSTS

Fielding Hardware Costs

The fielding hardware costs include any additional computer hardware necessary to allow the AI application users to operate the application.

Costs of Run-Time Software

Most AI development tools have a fee associated with delivery and operation of AI applications developed using the tool. A cost may also be associated with delivering the supporting database management tools.

Distribution and Publishing Costs

The distribution and publishing costs are the costs associated with producing the required number of copies of the AI application disks and the user and maintenance documentation.

Number of User Sites

The number of user sites is determined by the licensing agreement associated with delivery of the AI development tool. Some agreements define a site as an individual workstation while others define a site as a building or a mainframe computer.

Total Fielding Costs

$$\textit{Total fielding costs} = \textit{hardware cost} + (\textit{runtime costs} \times \textit{number of sites}) + \textit{distribution and publishing costs.}$$

MAINTENANCE COSTS

Maintenance costs of software are extremely difficult to determine prior to any maintenance history for the application. AI system software should have lower maintenance costs than that of conventional systems because the knowledge that the AI program contains has been separated from the logic of how the program uses its knowledge. Thus, maintenance cost savings are frequently counterbalanced by the enormous maintenance enhancement efforts that the use of expert systems creates. Industry studies indicate that conventional software maintenance costs account for as much as 50 percent of an organization's total Automatic Data Processing (ADP) budget [D-1]. More recent studies by the Electronic Industries Association (EIA) indicate that the maintenance cost of a software application may run as high as 60 percent to 70 percent of the LCC of the application. That estimate means that maintaining software costs 2 to 2 1/2 times the cost of developing the software.

Maintenance Hardware Costs

The maintenance hardware costs include all the hardware necessary to perform periodic updates and error corrections for an AI application. Many times a set of maintenance hardware can be used to maintain more than one AI application. When that is the case, only the percentage of hardware cost associated with maintaining a given application should be used.

Maintenance Software Costs

The maintenance software costs include the cost of the compilers, AI development tools, and other software necessary to perform periodic updates and error corrections for the AI application.

Maintenance Personnel Costs

The maintenance personnel costs are the costs of the expert, knowledge engineer, conventional programmers, policy representatives, and any other

personnel associated with maintaining the software. The costs should include the personnel salaries and the overhead costs associated with the personnel.

Distribution and Publication Costs

These costs are the costs associated with distributing the software updates and the revisions to the user manuals and maintenance manuals.

Expected Life of the System

The expected life of the system is the period of time from completion of development until the application has outlived its usefulness or is superseded by a newer application.

Total Maintenance Costs

$$\begin{aligned} \textit{Total maintenance costs} &= \textit{hardware costs} + \textit{software costs} \\ &\quad + (\textit{personnel costs} \times \textit{expected life}) \\ &\quad + \textit{distribution and publishing costs.} \end{aligned}$$

LIFE-CYCLE COST

The total LCC of the system is the sum of the development, fielding, and maintenance costs.

IDENTIFICATION OF BENEFITS

The standard model should consider benefits in the three areas described in the following subsections.

Benefits Derived from Increased Performance

Benefits derived from increased performance can generally be quantified as reduced manpower costs, more components produced per hour, manhour savings, or similar factors. The value of the increased number of components or manhour reductions is the benefit derived from increased performance.

Benefits Derived from Reduced Errors

Benefits derived from reduced errors are generally more difficult to quantify. They include reducing the cost to correct an error (in manhours) or reducing the cost to identify and replace a faulty component that was incorrectly repaired. A major

factor that affects the benefits derived from reduced errors is an accurate estimation of the error rate prior to implementing the AI system and the anticipated error rate after implementing it. The difference between those two figures times the cost of fixing the errors yields the total benefits derived from reduced errors.

Benefits Derived from Increased Consistency

These benefits are extremely difficult to quantify and are generally assessed best by higher command levels.

SELECTION OF PAYBACK MODEL

To simplify the process of determining payback on an AI application, and since most AI applications will be part of larger conventional data systems and weapon systems, the payback model used should be compatible with the funding source of the system of which the AI application is a part. If the AI application is stand-alone and the developers request funding through an established funding source [such as Productivity Investment Funding (PIF)], then the payback model is usually mandated by the existing funding source.

If the AI application developers request funds from a source established expressly for AI applications, the payback model used should be the one described herein. Whatever funding source is used, the organizations evaluating the requests for funds should be aware of the issues involved in AI applications and should be aware of the intangible benefits as well as the pitfalls of the AI applications.

SETTING PRIORITIES FOR AI PROJECTS

Priorities for proposed AI projects should be set in two steps. The first step is to apply the selection criteria discussed above to determine the appropriateness of AI for the projects. If a project is determined to be appropriate for use of AI technology, it passes to the second step in the process. In the second step, the relative worth of the project is determined and the priority is established.

Project Screening

Project screening is used simply as a filter to aid in increasing the probability of success of the projects that are eventually funded. Each project submitted is subject to the criteria described above depending on the specific AI technology involved. In the event that several AI technologies are involved, the project subcomponents are

subjected to the criteria described above, and only if each subcomponent is appropriate will the entire project be deemed appropriate.

This initial screening will determine whether an AI solution is possible for each nominated project and will also determine whether the technology is appropriate. This will increase the likelihood that the projects will be successfully completed.

Return on Investment

Priorities for the proposed projects are really established as part of the ROI evaluation. Priorities should be set only for those projects that are deemed to be appropriate in the project screening step. Furthermore, every project that enters this second step does so on an equal footing. Since the projects are evaluated in Step 1 using different selection criteria based on the technology involved, we cannot determine the relative value of projects. To try to set priorities for projects based on the outcome of the project screening would be like trying to say apples are better than oranges.

The ROI determination should look at two primary factors. The first factor is the tangible value of the project, that is, how much money the project will generate or save. The second factor is the intangible contribution to the using organization's mission effectiveness, that is, how much will the project contribute to national security. Since the relative contribution to mission effectiveness is difficult to quantify, the projects should first be ranked based upon the relatively tangible ROI. The intangible benefits should be used only in the case of a tie should two projects have the same tangible ROI.

Interoperability

When developing interoperable or common AI applications, three system components need to be considered: the user interface, the inference engine, and the domain knowledge. Developing AI systems with common user interfaces and inference engines greatly reduces the amount of time it takes system developers and users to adapt to new AI systems. The benefits expected from a common user interface and inference engine would be analogous to the benefits anticipated from developing conventional software in a common programming language like Ada. We strongly recommend that AI developers adopt common user interfaces and inference engines. They can do so in the same way that DoD adopts approved higher-order-

languages (HOLs) for conventional software. None of the current AI development tools is on the list of approved HOLs for defense system development. While existing HOLs, like Ada, may be sufficient for conventional software and may to some extent be used to implement simple AI systems, they are neither adequate nor efficient for developing most real-life AI applications. DoD needs to determine whether it desires to add existing development tools to the list of approved HOLs or if, like the Ada project, it wishes to develop a DoD proprietary tool for AI development. Adding AI development tools to the list of approved HOLs will aid in reducing the proliferation of different tools. The approval process for nonstandard tools should be the same as for other nonstandard HOLs.

Developing AI systems with common domain knowledge is difficult. Building specific domain applications that can be used across many functional areas is very difficult, and no definitive rules have been established for determining which applications are appropriate. One way that multiple organizations can develop AI systems is to have a central organization monitor all AI development efforts and facilitate the free exchange of ideas among the different AI development organizations. The central management organization can also form a cadre of development personnel that can assume development responsibilities for projects that span a large number of functional areas or services.

We recommend that wherever possible, DoD develop AI systems that can be used across many functional areas. While that approach may increase the initial development cost for some applications since the requirements of multiple organizations will have to be taken into account, the ROI should be higher because of the increased user base. Decision makers at all levels must be aware that the narrow application domain of AI systems makes it difficult to use seemingly similar applications across functional boundaries.

REFERENCE

[D-1] Yourdan and Constantine. *Structured Design*. Prentice-Hall, 1979.

APPENDIX E

THE MANAGEMENT OF ARTIFICIAL INTELLIGENCE PROJECTS

DEVELOPING AND ACQUIRING SYSTEMS

Artificial intelligence (AI) systems are developed to solve difficult problems whose solution process is subjective and frequently not well understood. Because of the nature of AI technology, development and acquisition documents, such as the system specification, appear somewhat later in the development cycle of AI software than they do in the conventional software development cycle. For that reason, it may be desirable to begin development of many AI systems in-house. In-house (i.e., organic) development can serve to prove the concept and can determine the appropriate scope of the application. Once the concept is proven and its scope is defined, the developers can decide whether to continue the development in-house or to do so under contract.

Location of Development Capabilities

The issue of where the development capabilities for AI projects should reside is complex. To develop an effective AI application, the developer must have detailed knowledge of the application domain, which would indicate that the development capability should reside with the users. However, many applications apply across organizational boundaries and require a detailed knowledge of the overall application domain and a broad vision of where the applications will be used and by whom. Those more-sophisticated applications would require a centralized development facility above the user level.

Most organizations and companies discussed in Chapter 2 of this report provide for both a decentralized and a centralized development capability. The primary development capabilities should reside with the users because they have the detailed domain knowledge that makes successful AI systems possible. However, a central organization needs to monitor the development activities to ensure cross-flow of information and to determine which, if any, of the development efforts will lead to a system that has applicability across organizational boundaries. When a system that can be used by many organizations is identified, the central organization needs to

have the authority to direct the developing organization to work with the other potential users to ensure everyone's requirements are incorporated into the system's design. The central organization must have some capability to enable it to either develop or contract those systems that have application across many organizational lines but for which no developers at the user level have been found.

Appropriate Acquisition Strategy

Acquisition personnel should be aware that the tasks performed by AI software are an order of magnitude more complex than those performed by conventional automatic data processing (ADP) or mission-critical software. A common technique, employed successfully for more than 10 years to rapidly develop AI software, is known as rapid prototyping. Rapid prototyping begins with a simple statement of requirements and uses the process of developing the software to generate and refine the system specifications. Only small, well-defined tasks are prototyped, and the system evolves as the tasks performed by each successive prototype encompass more and more of the total system functional requirement. A key component of rapid prototyping is the shell or tool used to develop the software. Developers using rapid prototyping techniques do not try to program directly in a higher order language (HOL) such as Ada, FORTRAN, or LISP. Rather, they use high-level programming tools or environments such as the Knowledge Engineering Environment (KEE), Smalltalk, or the numerous LISP programming environments. By using those environments, software developers are able to achieve 10-to-1 productivity increases over conventional programming techniques. Hence, rapid prototyping permits system replacement leadtimes to be considerably reduced from leadtimes of conventional software development efforts.

Organizations that plan to use AI to solve a problem should first develop a small prototype on a well-constrained part of the overall task. That process will enable the organization to better prepare detailed specifications for the full system. The prototype along with the specifications should then be provided to the final system developers as Government Furnished Equipment (GFE). Whether the system developer is another DoD organization or a contractor, the functioning prototype combined with the system specification will greatly aid the final system development activity.

No special review process is required for AI projects. The decision thresholds in place for the acquisition of existing systems should also be used for AI systems. However, organizations acquiring AI systems should ensure there is a continuous exchange of information between the system developers and the users. In contract situations this exchange will mean greater user involvement than may have been usual in conventional software development. It will also mean that the acquisition office will have to conduct more frequent technical interchange meetings with the system developers and more frequent design reviews.

An effective baselining and configuration control process is required for AI systems. It is impossible to complete and field an accurate and reliable system without this process. DoD already has an effective baselining and configuration control system described in the two software development standards, DoD-STD-2167A, *Defense System Software Development Standard*, and DoD-STD-2168, *Defense System Software Quality Program Standard*. Although these standards were established for conventional software, they are also applicable to AI software. Using these existing development and quality standards provides the added benefit of implementing a consistent software management policy across all types of software used in DoD.

Major unresolved issues still exist in contracting for AI systems. Currently, no standards govern AI development tools. DoD has established a list of approved programming languages for conventional software development, but to date, it has identified no standard AI development tools. DoD now has a prime opportunity to take the lead and establish a set of standard AI system development tools to avoid the proliferation of development tools experienced in conventional software. The Defense Advanced Research Projects Agency is currently working on developing an expert system development tool, ABE, that may establish a baseline from which to begin establishing standard AI development tools.

It remains to be seen what the best contracting methodologies for AI systems are. For small, well-defined systems, firm fixed price (FFP) contracts may be the best types to use. However, for larger, less-well-defined AI applications, contractors may be unwilling to accept the risk associated with a FFP contract and will insist on cost plus contracts. Cost plus contracts put a larger share of the risk on the Government.

especially in situations in which rapid prototyping begins without detailed specifications.

DoD should establish policies concerning standard AI development tools and contracting methodologies. It should examine how contractual obligations regarding performance of AI systems should be handled in statements of work (SOW) and specifications.

FIELDING SYSTEMS

Documentation Required for the Maintenance of AI Systems

AI software must be documented to enable system users and maintainers to effectively perform their respective functions. In 1987, the Electronic Industries Association (EIA) established a subgroup on the Management of Artificial Intelligence Software to address this issue. The committee's recommendations were documented in the EIA G-33 and G-34 Committee Proceedings. The group concluded that the documentation requirements described in DoD-STD-2167A were adequate for AI software provided that they were appropriately tailored. The committee's report describes suggested tailoring for several of the data item descriptions (DIDs) associated with DoD-STD-2167A.

The specific documentation required for an AI system varies with the size, complexity, critical nature of the application, method of procurement, and cost of the application. As the size, complexity, and cost of an application increases, the organization acquiring the system will wish to have greater insight into the actual development process. The procurement method may also have an impact on the amount of documentation required. In general, if the application is being developed using in-house resources, documentation is not required to the same level of detail as is required when the application is developed by an outside agency. These issues are fully discussed in DoD-HDBK-287, *A Tailoring Guide for DoD-STD-2167A, Defense System Software Development*. An expert system developed by the Air Force Acquisition Logistics Center, the Software Support Decision Aid, also identifies software documentation requirements.

As a minimum, every AI system developed should have a Software User's Manual, a Software Programmer's Manual, and a Software Design Document. The Software User's Manual provides the instructions necessary to allow the functional

users to operate the system. The Software Programmer's Manual, in many cases, consists of the commercial-off-the-shelf documentation that describes the operation and use of the AI tool used to develop the AI application. When the AI application is developed with other than an AI development tool, the Software Programmer's Manual should describe the operation and use of the programming language and environment, if any, used to develop the AI application. The Software Design Document describes in detail the structure and operation of the AI software. The Software Design Document should contain information on the physical structure of the AI software as well as all process flows. The complete content of these documents is described in the DIDs, DI-MCCR-80012A, DI-MCCR-80019A, and DI-MCCR-80021A.

Testing Required Prior to Fielding

Verification and validation must be considered when testing AI software. Verification is the set of procedures used to determine the correctness of the knowledge contained in the AI system; validation determines that the system satisfies the original statement of the requirement. Both should be performed on every system developed. However, for small systems which have relatively short development times and relatively low development costs, validation may not be cost-effective. Eliminating the validation will reduce the cost of implementing the system. For systems with short development periods (3 to 6 man months), the developers are not likely to stray from the original system requirements and the validation step may usually be safely eliminated. Rapid prototyping also increases the likelihood that the system will satisfy the original requirements without additional validation.

AI system verification must be performed. Verification is the only way to determine that the advice given by the AI system is correct and accurate. Since by their very nature AI systems do not conform to numeric algorithms, that when correct, are certain to give correct answers, their correctness cannot be proved, as is theoretically possible for conventional software. The usual method of performing system verification is to have the experts review the knowledge base entries for consistency and accuracy.

AI VALIDATION TECHNIQUES

The two techniques used to validate the accuracy of AI systems are the testimonial and the statistical methods. Whether the statistical method or testimonial method of evaluating AI systems is used, clear and precise evaluation criteria must be established at the time the system specifications are being developed.

When the functional requirements for the AI system are established, the criteria for an acceptable system must also be established. Test data (or cases) must be selected and a final qualification test must be performed prior to system acceptance. For example, a criterion might be that the system be able to process 100 test cases in a given amount of time and to provide 100 percent (or less if desired) correct recommendations.

Testimonial Method

The testimonial method is chosen when no test data are available with which to objectively measure the advice of the AI system. Such a situation occurs frequently with AI systems. The testimonial validation presents the AI system with a set of test cases to solve. The "solved" test cases are then provided to an expert or panel of experts for evaluation. The reviewing experts determine what percentage of the test cases are correct. If the percentage of test cases correct is high enough, the system passes validation. Some examples of applications for which this is the preferred method of validation are contract warranty selection, software documentation selection, inventory stocking level determination, and shop floor scheduling. All those examples are applications for which no answer is absolutely right or wrong and thus we have no objective way to verify the performance of the system.

Statistical Method

The statistical method is chosen when we have test data with which to objectively compare the advice of the AI system. The statistical method requires a set of known correct solutions to the test cases. The test cases are presented to the AI system and the AI system's advice is compared to the known correct results. If the AI system achieves a satisfactory number of correct answers, the system passes the test. Some examples of applications for which we have absolutely correct answers are fault isolation, repair, and data validation.

Neither of these testing methodologies takes into account the performance level of the AI system in relation to the performance of humans executing the same task. An expert system (ES) that provides correct advice on 45 percent of all test cases may not appear to have an acceptable level of performance. However, the benefits of the ES are clear when one realizes that the average human performing the same task only gets, for example, 20 percent of the test cases correct. Therefore, test cases should be tested against both the AI system and a representative sample of humans. We can then measure the performance of the AI system relative to that of humans doing the same tasks.

MAINTAINING AI SYSTEMS

While AI systems such as rule-based ES may be easier to maintain than conventional systems of similar complexity, AI systems tend to be modified more frequently than conventional software. This increased frequency of modification stems from two factors. First, since some AI software is easier to modify than conventional software, users tend to ask for more frequent changes than they would if they knew it would take a long time to implement the change. Second, the level of knowledge that such AI systems as ES deal with is more familiar to the users than the level of knowledge in conventional software. For that reason, users are more aware of how ES operate and, therefore, request more frequent changes to match the changes in how they do their jobs. Because of the frequency of changes to AI software and the level of domain knowledge contained in the application, domain experts and users must be involved in maintaining AI software.

A large percentage of AI systems may be developed by end users, and end users rarely anticipate the level of effort required to maintain an operational system. As a result, they tend to overextend their resources. However, since end users better understand their operational requirements, procedures must be established to allow them to develop their own systems and transfer the maintenance of those systems to a maintenance organization for long-term support. That practice will ensure needed systems are developed on a timely basis while reducing the software support burden on the end users. This will also allow the different organizations to concentrate their AI system support personnel and more effectively allocate these valuable resources.

If the using organization is also the developing organization, there is no major problem with the users maintaining their own systems. However, in situations in

which the users have not developed the system or the system is used by many organizations, the issues of configuration control and management become much more critical. In those situations, the maintenance should be left to a central support center with expertise in software configuration management. Even those systems developed and maintained by the end users require some configuration management and should be maintained by a single person or group within the user's organization.

The developers of any large system should consider fielding an automated knowledge acquisition system along with the operational system so that the users can easily update the knowledge in their AI system without having to manually alter any system code. Automated knowledge acquisition systems can greatly facilitate the job of acquiring the new knowledge necessary to maintain and modify an existing system. The trade-off that must be examined, when considering the development of a knowledge acquisition system, is the cost of developing the knowledge acquisition system versus the cost of manually maintaining the AI system. Automated knowledge acquisition systems are economically justified for only very large systems. In some cases, the development cost of the knowledge acquisition system may equal the cost of developing the operational knowledge system. DoD should examine closely the cost of maintaining a very large knowledge system. If that cost will be greater than 70 percent to 80 percent of the total life-cycle cost (LCC) of the system, the developers should strongly consider developing an automated knowledge acquisition system.